DENVER INTERNATIONAL AIRPORT

DESIGN STANDARDS MANUAL

Mechanical

Design, Engineering and Construction

Revised: Q4 2023

Included Technical Specification Requirements	Manual
Division 02: Existing Conditions	Architecture
Division 03: Concrete	Civil
Division 04: Masonry	Structural
Division 05: Metals	Architecture
Division 06: Wood, Plastics, and Composites	Architecture
Division 07: Thermal and Moisture Protection	Architecture
Division 08: Openings	Architecture
Division 09: Finishes	Architecture
Division 10: Specialties	Architecture
Division 11: Equipment	Architecture
Division 12: Furnishings	Architecture
Division 13: Special Construction	Structural
Division 14: Conveying Equipment	Architecture
Division 21: Fire Suppression	Life Safety
Division 22: Plumbing	**Mechanical**
Division 23: Heating, Ventilating, and Air-Conditioning (HVAC)	**Mechanical**
Division 26: Electrical	Electrical
Division 27: Communications	Communication & Electronic Systems
Division 28: Electronic Safety and Security	Communication & Electronic Systems
Division 31: Earthwork	Civil
Division 32: Exterior Improvements	Civil
Division 33: Utilities	Civil

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Table of Contents

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Table of Figures

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Table of Tables

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Summary of Revisions

The following tables list the revisions to the Mechanical DSM within the past year.

2023 Revisions

Fourth Quarter

Reference	Revision Description
Throughout	Design temperatures for non-CCD areas that are not subject to Executive Order 123
Throughout	Corrections to text formatting
Table 1-1: Definitions	Added definition for Terminal Complex
1.0.5 Regulatory Requirements	Inclusion of Environmental and Sustainability Stakeholders
1.0.6 Work Sequence, Coordination, and Installation	Design including duplication of Appurtenances
1.0.7 Site Conditions	Designers having a better understanding of existing systems
1.1.1 System Criteria	Inclusion of specific Stakeholders, Inclusion of special considerations to the floor plans, Existing systems needing modifications, Provisions for Temporary Equipment or bypass
1.1.2.3 Indoor Design Temperatures	Indoor design temperature changes for non-CCD areas.
1.4.1 Design Submittals	Identify equipment nuances to reviewers
2.0.1 Existing Campus Heating/Cooling Systems Operation	Updated for ongoing work
2.1.4 Boilers	Updated for ongoing work
2.1.8 Water Treatment	Updated for recent work.
2.1.14 Heating System	Updates to Heating System Operation
3.5.6 Food and Beverage Tenant Equipment	Reference to Chapter 5 for tenant controls requirements added.
5.0.1 General	Added clarification for non-HVAC controls, Equipment manufacturer controls system requirements, Tenant alarming and integration into the EMCS, Location of sensors.
5.2.9 Thermostats and Temperature Sensors	Displays on temperature sensors.

Fourth Quarter (Continued)

Reference	Revision Description
5.4 Sequence of Operation	Designer to research and coordinate integration of new systems into the legacy systems.
6.1.3 Hydronic Requirements	Updated heating water supply and return temperatures to match current operations, Limit height of devices requiring service.
6.1.5 Piping and Valves	Reliance on existing valves and installing a bypass on mains.
6.1.6 Pumps	Include high-performance shaft seals and a spare
6.2.2 Flushing and Cleaning for Closed Hydronic Systems- Metallic Piping Systems	New section
8.1.15 HVAC Coil Condensate Drains	Added condensate drain terminations
8.5.4 Water Meters	Defined threshold for metering requirements
10.0.6.2 CUP Connection Criteria	Updated heating water temperatures
10.3.1 Ventilation and Conditioning	Updated requirements
Chapter 11: Facility Design	Temperature updates in the Design Conditions for most facilities, Updated plumbing requirements
11.14.2 Air Handling Systems	Updated location of air handling units
11.15.2 Air Handling Systems	Updated location of air handling units
11.19.2 Air Handling Systems	Updated location of air handling units
11.20.2 Air Handling Systems	Updated location of air handling units
11.26.1 Design Conditions	Cooling set points for City occupied spaces per XO-123
11.43.2 Ventilation System & 11.43.3 Exhaust Fan Controls	Updated existing conditions
11.44.5 Electrical Rooms	Added electrical room cooling requirements
Chapter 12: Technical Specification Requirements	Corrections to text and formatting throughout the chapter
Section 220500: Common Work Results for Plumbing Equipment	3.01 Piping Systems- Common Requirements: Added high point vents and low point drains
Section 220516: Expansion Fittings and Loops for Plumbing Piping	Updated flexible pump connectors. Engineering Notes: Added specific types of pump connectors.
Table 12-2: Division 23 DEN Standard Specifications	Removed sections 230993 & 238126 from list of Standard Specifications

Fourth Quarter (Continued)

Reference	Revision Description
Section 220719: Plumbing Piping Insulation	Added information on insulation jacketing
Section 221113: Facility Water Distribution Piping	Removed PVC Piping for aboveground water-service piping and updated allowed piping materials
Section 221116: Domestic Water Piping	Removed CPVC and PVC Piping for aboveground domestic water piping NPS 2 and smaller and updated allowed piping materials
Section 221119: Domestic Water Piping Specialties	Added engineering note for water meter controls integration.
Section 230400: Basic HVAC Requirements	Added section 3.01 - Flushing and cleaning for closed hydronic systems – metallic piping systems
Section 230500: Common Work Results for HVAC Equipment	No flange-to-flange connections allowed. Exclusion of the installation of valves beyond what is shown in the documents. Include chain-up device and safety restraint system for valves using chainwheels. Added high point vents and low point drains.
Section 230516: Expansion Fittings and Loops for HVAC Piping	Updated flexible pump connectors
Section 230519: Meters and Gauges for HVAC Piping	Added locations for Test Ports
Section 230523.11: Globe Valves for HVAC Piping	Updated specification designation from 230523.44 to 230523.11 for Globe Valves
Section 230523.12: Ball Valves for HVAC Piping	Added chain-up devices for ball valves
Section 230523.13: Butterfly Valves for HVAC Piping	Added chain-up devices for ball valves
Section 230523.14: Check Valves for HVAC Piping	Corrections to section 3.02 VALVE INSTALLATION for check valves
Section 230523.16: Plug Valves for HVAC Piping	Added chain-up devices for ball valves
Section 230716: HVAC Equipment Insulation	Section 3.02 INSTALLATION OF EQUIPMENT, TANK, AND VESSEL INSULATION is added.
Section 230719: HVAC Piping Insulation	Updated requirements for the painting of pipe insulation
Section 230800: Commissioning of HVAC	Added section
Section 230923.14: Flow Instruments & Section 230923.17: Level Instruments	Limit height of remote displays

Fourth Quarter (Continued)

Reference	Revision Description
Section 231113: Facility Fuel-Oil Piping & Section 231123 Facility Natural-Gas Piping	Updated requirements for the painting of the pipe
Section 232113: Hydronic Piping	Broaden system types in 3.01 PIPING APPLICATIONS. Updated section 3.02 PIPING INSTALLATIONS for additional requirements.
Section 232123: Hydronic Pumps	Added requirements for pump seals

Second Quarter

Reference	Revision Description
Throughout	Minor punctuation and grammar changes
1.1.7 Supports and Penetrations	Added information on supports and anchors
3.5.6 Food and Beverage Tenant Equipment	Added information on what should be included in inspection report
Section 230923: Direct Digital Control (DDC) System for HVAC	Added note on Tenant Water and BTU Meters
Section 232113: Hydronic Piping	Added Filter Backwash Piping information

2022 Revisions

Fourth Quarter

Reference	Revision Description
Throughout	Minor punctuation and grammar changes
Table 1-1: Definitions	Added SARA (Service Animal Relief Area)
1.1.2.1 Design Parameters	Updated current ASHRAE Design Conditions information
1.1.2.2 Design Conditions Prior to 2022	Added section describing Design Conditions prior to 2022
3.0.1 Air Handling Systems	Added information linking to new Sustainability section
3.5.2 Existing Base Building Mechanical Design Capabilities	Added mechanical design capabilities for the concourse expansions
3.5.6 Food and Beverage Tenant Equipment	Added information on Tenant kitchens use of scrubbers in grease exhaust
3.6 Sustainability	Added section on Energize Denver Ordinance

Fourth Quarter (Continued)

Reference	Revision Description
4.0.7 VAV Terminal Air Units	Updated information from Honeywell to Johnson Controls MetaSys
5.0.2 Existing Base Building HVAC Control Systems	Added information on transitioning to Johnson Controls
5.0.3 New and Replacement HVAC Control Systems	Removed Honeywell information and added information on who to consult for existing controls
8.1.1 General	Added information on Sewer Use and Drainage Permit
Table 8-1: Grease Trap Capacities	Added new Tag information
8.1.16 Secondary Condensate Drains	Added information on signage
8.4.4 Sustainability	Added section on Energize Denver Ordinance about no new gas-fired equipment
8.5.1 Plumbing Requirements	Added link to 8.2.3 Piping
8.5.3 Water Heaters	Added link to 8.4.4 Sustainability (reducing carbon emissions at DEN)
10.0.6.2 CUP Connection Criteria	Added information on equipment operating temperature and proper equipment operation
10.1.1 PCA Unit Sizing	Added example of what PCA should be able to handle
10.1.2 United Airlines PCA Hose Adapters/ Connectors	Added section on United Airlines PCA Hose Adapters/Connectors
10.3.2 PLB Pressure Monitoring	Added/updated information on PLB monitoring
11.21 Domestic Concourse – Service Animal Relief Areas (SARA)	Added section on Service Animal Relief Areas (SARA)
Section 220529: Hangers and Supports for Plumbing Piping and Equipment	Added Hanger and Support Installation
Section 220553: Identification for Plumbing Piping and Equipment	Removed information from Piping Identification Schedule
Section 230923: Direct Digital Control (DDC) System for HVAC	Added note on coordinating specifications
Section 230923.12: Control Dampers	Added information about removing Honeywell as accepted manufacturer
Section 230923.14: Flow Instruments	Added information about removing Honeywell as accepted manufacturer

Fourth Quarter (Continued)

Reference	Revision Description
Section 230923.17: Level Instruments	Added information about removing Honeywell as accepted manufacturer
Section 233300: Air Duct Accessories	Added Duct Security Bars information
Matrix A: DEN Concourse A West Expansion Concessions	Added new matrix
Matrix B: DEN CEP Concourse B West Expansion Concessions	Added new matrix
Matrix C: DEN Concourse C East Expansion Concessions	Added new matrix

Second Quarter

Reference	Revised Description
Throughout	Minor punctuation and grammar changes
Table 1-1: Definitions	Added Direct Digital Controls and Design Standards Manual definitions
2.0.1 Existing Campus Heating/Cooling Systems Operation	Updated requirements of existing system and future system
2.1.4 Boilers	Updated requirements of existing system and future system
3.0.5 Roof-Mounted HVAC Systems	Revised description and added new information
4.0.3 Dampers	Revised descriptions for General, Existing Base Building HVAC Control Systems, and New and Replacement HVAC Control Systems
5.0 Controls	Revised title and descriptions for Software and Trend Logging and Graphing
5.3 Central Control Systems for Main Airport Buildings	Revised descriptions for Hydronic Requirements and Piping and Valves
6.1 Equipment	Revised description
6.5.1 Flow Diagrams	Revised description
8.1.7 Grease Traps	Revised description
8.2.3 Piping	Revised description
8.5.2 Grease Waste	Revised Frontier Single Bridge PCA1
Table 10-2: Sizing of Aircraft Specific to DEN	Revised description

Second Quarter (Continued)

Reference	Revised Description
10.5.1 Flow Diagrams	Added new section under PART 3 EXECUTION
Section 230400: Basic HVAC Requirements	Added new information under 2.01 MANUFACTUERS, revised information under 2.10 DDC CONTROLLERS
Section 230923: Direct Digital Control (DDC) System for HVAC	Revised Engineer spec note under PRODUCTS
Section 230923.11: Control Valves	Revised Engineer note under PART 2 PRODUCTS
Section 230923.12: Control Dampers	Revised and added new information under 3.02 PIPING INSTALLATIONS
Section 232113: Hydronic Piping	Added new engineer note under 2.13 HANGARS AND SUPPORTS
Section 233113: Metal Ducts	Minor punctuation and grammar changes

Revision Notation: Revisions made to this Manual during this revision cycle are annotated as shown in the example below:

A vertical line in the left-hand margin is used to annotate paragraphs that have been added or revised in the current publication. Revisions may include items such as new requirements, clarification of existing requirements, or removal of requirements that no longer apply to projects. Revision annotation is applied to each publication individually; revisions made in past publications are not annotated in subsequent publications.

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Purpose of Design Standards Manuals

The DEN Design Standards have been developed to ensure a unified and consistent approach to the thematic and technical design for DEN. These standards are for use and strict implementation by all consultants under contract to DEN, to tenants, and all other consultants under contract to any other entity for the design of projects at DEN.

The Standards Manuals are working documents, which will be revised and updated, as required, to address the general, conceptual, design, and technical standards for all areas of design for DEN.

This Design Standards Manuals (DSM) for DEN has been prepared for use by competent, professionally licensed architectural and engineering consultants under the direction of DEN Maintenance and Engineering or tenants of DEN.

The Design Standards shall not be quoted, copied, or referenced in any bidding or construction contract documents. Content contained in this Manual shall not be copied in any bidding or construction documents, except where specifically instructed to do so. All information contained in these standards must be fully explained and shown in all bidding and contract documents.

The Design Standards Manuals are intended to be used as a whole, as each manual is complimentary to the other DSMs. To understand the overall thematic and design standards for DEN, the applicable manuals must be utilized together and not separated from the Design Standards Manuals.

The Consultant shall not reproduce, duplicate in any manner, transmit to other consultants or other entities, or use in conjunction with other projects without the express written consent of DEN.

NOTE: This document is optimized for duplex (double-sided) printing.

VARIANCE FROM DEN DESIGN STANDARDS MANUALS

Requests for non-conformance or variance from DEN Design Standards manuals, for any DEN or Tenant Projects, must be formally submitted using the online DSM Variance Request form at the following website:

DEN DSM Variance Request Form

Variance requests may or may not be approved by DEN and response will be communicated to the requestor.

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Chapter 1 - General

1.0 General

1.0.1 Intent

The Mechanical systems consist of HVAC, plumbing, fire protection, automatic controls, and process systems located in the terminal building, the Airport Office Building, concourses, and outlying support buildings. The goals and objectives are to develop a Mechanical design to achieve an efficient, economical, maintainable, and reliable installation consistent with the goals and objectives of the Denver International Airport/City and County of Denver.

The space environment shall be designed to be controllable within an acceptable year around comfort and health levels. The Design Engineer shall utilize the latest state-of-the-art, energy-conservative, readily available equipment and components based on proven design techniques.

1.0.2 Definitions

The following terminology is used throughout this manual.

Table 1-1: Definitions

Term	Definition
AFF	Above Finish Floor
AGTS	Automated Guided Transit System. The AGTS is the train that travels between the airport terminal and concourses.
ALP	Airport Layout Plan
AOB	Airport Office Building
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BIM	Building Information Management. The BIM system consists of 3-D models in Revit, Civil 3D, and interfaces to CMMS systems.
BTU	British Thermal Unit
CCD or City	City and County of Denver
CFM	Cubic feet per minute
CMMS	Computerized Maintenance Management Software
Concealed	Embedded in masonry or other construction, installed in furred spaces, within double partitions or hung ceilings, in trenches, in crawl spaces, in soffits, or in enclosures.
Contractor	Tenant’s contractor and sub-contractors
Control or actuating devices	Automatic sensing and switching devices such as thermostats, pressure, float, electro-pneumatic switches, and electrodes controlling operation of equipment.
CUP	Central Utility Plant
DEC	Design, Engineering, and Construction. DEC is a division within DEN.
Designer	Designer of Record

Table 1-1: Definitions (Continued)

Term	Definition
DDC	Direct Digital Controls in a centralized network-oriented approach to control systems that are integrated into the EMCS including HVAC, Electrical Metering, Lighting, and others. Reference the Communication & Electronic Systems DSM for other items included in the Controls Network.
DDS	Denver Development Services. DDS is the Denver Building Department.
DEN	Denver International Airport. DEN is operated by the City and County of Denver's Department of Aviation.
DFD	Denver Fire Department
DSM	Design Standards Manual
ECS	Emergency Communication System
EMCS	Energy Management Control System
EMS	Emergency Management System
Exposed	Not installed underground or concealed as defined above
Furnish	To supply and deliver to the project site, ready for unloading, unpacking, assembly, and installation as applicable to the project, unless noted otherwise.
GPM	Gallons per minute
HTC	Hotel and Transit Center
HVAC	Heating, Ventilating, Air Conditioning systems
HV	Heating, Ventilating systems
Install	Operations at the project site including unloading, unpacking, assembly, erection, placing, anchoring, applying, working to dimension, finishing, curing, protection, and cleaning as applicable to the project, unless noted otherwise.
LEED	Leadership in Energy and Environmental Design. LEED consists of a suite of rating systems for the design, construction, and operation of high performance, homes, and neighborhoods.
Material	All mechanical system components required for project construction including equipment.
Mechanical Systems	HVAC, plumbing, fire protection, and related control systems as contained herein.
Motor Controllers	Manual or magnetic starters (with or without disconnects), individual push buttons or hand-off-automatic switches controlling the operations of motors.
Piping	Pipe, tube, fittings, flanges, valves, controls, strainers, hangers, supports, unions, traps, drains, insulation, and related items.
PM	Project Manager. The PM is the Project Engineering representative of DEN.
Provide	To furnish and install as defined herein.

Table 1-1: Definitions (Continued)

Term	Definition
Related work	Includes, but is not necessarily limited to, mentioned work associated with, or affected by, the work specified. All related work is included as work of this division unless otherwise specifically excluded.
SARA	Service Animal Relief Area
SF	Square feet
Similar or equal	Equal in materials, weight, size, design, capacity, performance, and efficiency of specified product.
Supply	To purchase, procure, acquire, and deliver complete with related accessories.
Tenant	Lessee to the City and County of Denver and DEN, including the Tenant's Architectural/Engineering Consultants.
Terminal Complex	Refers to the Main Terminal (Great Hall), Concourses A,B, & C, Central Utility Plant (CUP), Hotel, and the Transportation Center.
Wiring	Raceway, fittings, conduit, wire, boxes, and related items
Work	Labor, materials, equipment, fixtures, trim, apparatus, controls, accessories, and other items required for proper and complete installation.

1.0.3 General

The Designer shall prepare the design, construction documents, drawing, and specifications for HVAC equipment, ductwork and piping, exhaust equipment, controls, insulation, structural, plumbing, fire protection, automatic control systems, energy management systems, and operational services such as aircraft and vehicle fuel and glycol systems. The Designer shall coordinate the mechanical design with the applicable sections of the architectural, electrical, structural, civil, and DEN standards and criteria.

All construction documents shall be developed by the designer and reflect a complete engineered design. The installing contractor may perform certain engineering tasks, such as fire protection, but the designer is responsible for the total overall design.

1.0.4 DEN Mechanical Engineer

All references in this document to the DEN Mechanical Engineer refer to the individual listed below. For questions, updates, or requests for deviations to this document, contact:

Manager of Systems Engineering
Design, Engineering, and Construction
8500 Pena Blvd, 7th Floor AOB
Denver, CO 80249-6340

1.0.5 Regulatory Requirements

Designers shall specify that work shall be per underwriters; public utility; local; state, and federal codes; ordinances; and applicable regulations. Work shall also comply with the latest editions of all applicable codes, ordinances, and regulations in effect as of the date of the contract documents. If discrepancies occur between the contract documents and any applicable codes, ordinances, acts, or standards, the most stringent requirements shall apply. Where hourly fire ratings are indicated or required, designs shall provide for components and assemblies meeting the requirements of the American Insurance Association, Industrial Risk Insurers, Factory Mutual Insurance Association, and listed by Underwriters Laboratories, Inc.

Designers shall include stakeholders from DEN Environmental and DEN Sustainability for DEN specific requirements. An example is the requirement that flue gas monitoring ports be added to flues, and environmental permits be indicated in the construction documents and specifications when necessary in the project.

1.0.6 Work Sequence, Coordination, and Installation

Project documents shall be developed so that work is furnished and installed in a logical sequence and performed in an expeditious manner for an efficient flow of work. Attention is to be given to the positioning of large equipment items and tie-ins to existing systems that will require system shutdowns. Progress of mechanical work shall be coordinated with other trades.

All site conditions and dimensions shall be verified by field measurements. Chases, slots, and openings shall be verified and designed to allow for mechanical installation. When mounting heights are not specifically detailed or dimensioned, systems, materials, and equipment are to be installed to provide the maximum headroom possible with minimum headroom of 7'-6" above the finished floor (AFF). If there are spaces with finished ceilings, the systems shall be of adequate height above the ceiling.

All systems that require periodic servicing or equipment replacement shall be readily accessible from the space. Coordinate connection of mechanical systems with exterior underground and utility services.

Contract drawings shall indicate the general arrangement of mechanical systems. Information shown may be schematic. Field verification by the designer of all existing architectural, mechanical, electrical, civil, and structural system locations is required.

Drawings and specifications are to complement each other. The designer shall clearly identify any work, materials, or equipment indicated on the drawings but not described by the specifications or described by the specifications but not shown on the drawings. In case of a conflict, the Contractor shall obtain clarification from the designer through the DEN PM in writing prior to bidding the job. After the job is bid, the conflict shall be resolved at the sole discretion of the DEN PM.

Although the general criteria may not be specifically indicated, Designers shall design and specify all supplementary or miscellaneous items, appurtenances, and devices incidental to or necessary for a complete mechanical system. Designers are to coordinate with devices being installed to prevent duplication of appurtenances internal to the device.

The designer shall fully detail all demolition drawings, and all unused mechanical and plumbing systems shall be demolished. No mechanical or plumbing systems, including equipment, ductwork, piping, supports, controls, power conduit, etc., shall be abandoned in place.

1.0.7 Site Conditions

The designer shall field verify the site location and availability of existing mechanical and electrical systems and the building structure. The designer shall examine site premises and utilities to become familiar with existing local conditions affecting work, such as obstructions, levels, necessary cutting, and any other existing services, before submitting the design. Designer shall research and coordinate with the appropriate stakeholders until a thorough understanding of how existing systems and equipment operate. Construction documents are to include the integration of new and existing equipment services with any upgrades in existing equipment or service necessary for proper operation. No allowance will subsequently be made due to any misunderstanding with respect to existing site conditions. All possible interferences inhibiting the routing of services shall be verified.

1.1 Design Criteria

1.1.1 System Criteria

The mechanical systems for all facilities at DEN are to be based on straightforward, proven design techniques utilizing the latest state-of-the-art development in readily available equipment and hardware. The overriding criteria for the use of systems and equipment shall be the safety, convenience of maintenance, simplicity, and comfort of the traveling public.

It is most important that the systems installed serve the public well, are readily serviceable and maintainable, are stable and direct in their operation, and provide flexibility for future change and development. All equipment, appurtenances, and hardware shall be accessible for adjustment and maintenance. Suitable access is required to permit the removal and replacement of equipment items. Provisions are to be made for the centralization of operating and maintenance diagnostics.

Include stakeholders in evaluating the condition of the existing systems to be modified for their input and experience during the development of any designs. Work in the Terminal Complex should involve at a minimum the HVAC Maintenance, Electrical, and Plumbing Supervisors input for any nuances that the designers should be aware of effecting their designs. Work in the CUP or any system served from the CUP in the Terminal Complex shall also require input from the Utility Plant Supervisor. Specifically include DEN Mechanical, Life Safety, and Electrical Engineers in any decisions needed in the progress of the designs. Other stakeholders to include would be DEN Environmental and DEN Sustainability at a minimum for requirements specifically to DEN systems. Record and include in the design analysis report (DAR) decisions and notes from any conversations that support those decisions for future reference.

Equipment and or major components that are routinely replaced weighing over 100 pounds and the top of the equipment located more than 60 inches above the finish floor shall have an equipment removal system. The system shall, at a minimum, allow for a chain fall to be mounted and the equipment to be safely moved. This system shall be designed by a Colorado Licensed Structural Engineer and be approved by the DEN Mechanical engineer. Alternate methods for lifting heavy equipment for maintenance may be considered but must be approved by the DEN Mechanical Engineer by the 60% (or equivalent) Contract Document submittal.

Equipment or devices requiring special considerations shall be included in the design and not left up to the contractor as a requirement in the specifications. This includes designing and depicting on floor plans the required straight pipe and straight duct for measuring devices, locating control items such as outdoor pressure sensors, duct static pressure sensor locations, and similar items.

High discharge flows from backflow preventors, relief valves, hydronic blowdown and similar shall discharge into a receptor with adequate capacity to accept the entire flow without overflow. Design is to include any modifications needed to the existing drainage systems. Alternate methods of accepting high discharge rates must be approved in writing by the Mechanical Engineer prior to implementation to the design documents.

It is anticipated that there will be changes and development in many areas of the airport facilities, and the mechanical systems must be revised or expanded to accommodate these changes. In addition, development in state-of-the-art technology may suggest updating systems and system components in the future. All designs of mechanical systems must include built-in flexibility in keeping with the nature of change that is present for air transportation facilities.

Much of the existing equipment no longer functions according to the original intent and may be replaced. Old equipment, isolation valves, control valves, etc. are to be evaluated and included in the project scope as necessary for adequate installation and operation of the new and replaced systems. Provisions for temporary systems needed for permanent equipment installation shall be included in the design. Examples include indication of temporary heating/cooling equipment if any main hydronic or ducting work is to occur, installation of temporary bypass piping or ducting to minimize the impact of the “downstream” components affected. Do not rely on existing isolation valves to hold for new piping or equipment replacement but include provisions for the replacement of existing or the addition of new isolation valves and method of temporarily isolating the systems for minimum impact to the airport facilities.

In addition, energy conservation and cost savings will also be guiding criteria in the design of mechanical systems. All facilities must meet the energy conservation requirements included in these standards. Both initial system and equipment costs and life cycle owning, operating, and maintenance costs are to be important considerations in concept design efforts, and these considerations must be carried through final design and construction.

Simplicity in operations and maintenance is key to efficiently running a large air transportation facility. Where possible, Consultants shall reduce or eliminate redundant systems and equipment or sequences of operation. DEN staff understand that certain provisions in the Design Standards Manuals, codes, and regulations, and project-specific requirements or constraints may necessitate the use of redundant systems, equipment, or sequences of operation. In these instances, the Consultant shall provide a narrative describing what requirement necessitates the use of the redundant systems, equipment, or sequences of operation in the Design Criteria section of the DAR. Refer to Chapter 3 of the Standards and Criteria DSM for more information.

1.1.2 Mechanical Design Criteria - Flexibility

Special provisions are to be made in determining terminal and concourse building heating and air conditioning load requirements to properly allow for the dynamic nature of the application of these loads. During normal operation, these loads can vary dramatically from zone to zone, and the peak load can fluctuate significantly within each zone. This is due to the rapid mass movement of people within the building, as well as the shifting solar load on glass walls, infiltration loads associated with people and baggage movement in and out of the building, and outside air ventilation requirements.

Heating and air conditioning system controls must provide system flexibility to satisfy the shifting internal cooling loads. The HVAC system must be able to handle varying perimeter loads during heating and cooling seasons while the internal and other loads fluctuate between no load and peak conditions. In addition, appropriate air quality conditions must be maintained in the spaces while the natural/nearby ambient (outside) conditions are very often of less than ideal quality.

1.1.2.1 Design Parameters

All new systems or major modifications to existing systems shall be designed and selected based on the latest ASHRAE Standards 90.1 and 55 requirements. Design conditions for DEN according to the latest version of *ASHRAE Standard 169 - Climatic Data for Building Design Standards.*

Historical Reference: Many existing base building systems were designed and selected based on the following design conditions:

1.1.2.2 Design Conditions Prior to 2022

Design conditions for DEN according to *ASHRAE Handbook - Fundamentals 2013* are as follows (rounding to the nearest degree F):

A. Cooling at the 1% level: 92°F (DB)/60°F (MCWB)
B. Evaporation at the 1% level: 64°F (WB)/81°F (MCDB)
C. Heating at the 99.6% level: 1°F (DB)

1.1.2.3 Indoor Design Temperatures

It is intended that the mechanical systems (in general) maintain indoor design conditions in all occupied spaces normally accessible to the public as follows (unless specified otherwise):

A. Summer: 75°F, 50% maximum relative humidity
B. Winter: 72°F

1.1.2.4 Outdoor Design Temperatures:

Original outdoor design conditions used for system designs are as follows:

A. Summer: 92°F dry bulb/59°F wet bulb (coincident conditions)

   96°F air-cooled condensing temperature

   63°F wet bulb design condition.

B. Winter:-5°F

   These design criteria conditions are based on the recommended conditions listed for areas near Denver in the *1987 ASHRAE Fundamentals Handbook* at the 2-1/2% summer condition and the 99% winter condition. That is, based on historical data, the outdoor temperatures can be expected to exceed the summer design conditions 2-1/2% of the time and exceed the winter design conditions 1% of the time.

   The more stringent design condition is required for winter criteria due to the inherent outdoor air infiltration condition present in most airport situations. The design wet bulb condition is based on the 2-1/2% mean coincident wet-bulb condition.

1.1.3 Ventilation Standards

All new systems or major modifications to existing systems shall be designed and selected based on the latest version of ASHRAE standard 62.1 or the IMC, including CCD amendments; whichever is more stringent.

Historical Reference: Many existing base building systems were designed and selected to meet the following:

Ventilation Standards for occupied spaces are to be based upon ASHRAE standard 62-1989, *Ventilation for Acceptable Indoor Air Quality*. The minimum required ventilation rate of outdoor air per person is to be 15 CFM per person, with several special-use areas in the buildings having significantly higher requirements. The distinction between smoking permitted and smoking prohibited has been abandoned in the revised standard; Denver Executive Order No. 99 prohibits smoking in all indoor public places, including bars, restaurants, and food courts.

1.1.4 Energy Efficiency Requirements

Energy efficiency is an important consideration in the design of mechanical systems for all DEN facilities. Heating, ventilating, and air conditioning systems are to be designed to meet or exceed the requirements of the latest version of ASHRAE standard 90.1- *Energy Efficient Design of New Buildings except for Low-Rise Residential Buildings* and the CCD building code. Projects seeking LEED certification must meet all requirements to achieve LEED Gold certification or higher as defined by CCD Executive Order 123.

Equipment selections must be specified to meet or exceed these standards. The equipment and systems described herein must be selected to obtain the optimum in conserving life cycle owning and operating costs considering energy efficiency, initial costs, maintainability, and comfort. Refer to Chapter 9- Energy Analysis and LEED for further information on energy performance criteria and energy analysis.

1.1.5 Noise Criteria

The mechanical (HVAC) system shall be designed to minimize noise in the occupied space. The system and components shall be designed so as not to transmit or generate sound above a specified noise level in the space. Sound attenuators, duct liner, lower duct velocities and appropriate ductwork fittings and components shall be utilized as required to attain acceptable sound levels. Vibration isolation shall also be evaluated and utilized. Sound attenuators shall be isolated from the building structure.

For all HVAC and sound attenuation equipment provide schedules defining sound pressure levels in all 8-octave bands in dBA and calculated Noise Criteria (NC).

Sound tests shall be conducted in accordance with accepted procedural standards in and around all major sound-producing equipment either to confirm adequate attenuation or to identify problem areas requiring additional modifications as required by the DEN PM.

Maximum noise levels in the occupied space produced by HVAC equipment shall be in accordance with the NC curves listed in Table 1-2: NC Criteria by Space.

Table 1-2: NC Criteria by Space

Occupied Space	NC Curve
Main Terminal	40
Concourse	40
Baggage Handling Areas	45
Restaurant and Food Service	40
Retail	40
Private Lounges	35
Offices	35
Conference Room	30
Control Tower Offices	35
AARF Station	35
Maintenance Work Area	45
Hotel Rooms	30
Mechanical Equipment Room	50

Notes:

- *For NC curves, the lower number, the quieter the background noise*
- *Noise is to be free of tonality.*
- *Noise is to be free of low frequency time modulations (fluctuations).*
- *For any additional spaces not listed in the table above, refer to the NC Curves in the latest*
- *AHRAE Handbook - HVAC applications or other applicable standards.*

Where mechanical noise is to be utilized for sound masking, RC (room criteria) curves shall be utilized as described in Chapter 8, Sound and Vibration of the most recent *ASHRAE Handbook, Fundamentals*.

Equipment and ductwork noise levels to permit attaining sound pressure levels in all 8-octave bands in Tenant occupied spaces shall conform to noise criteria NC-35 curves. Motor drives for pumps or any equipment shall operate with noise levels not exceeding OSHA 8-hour 90dBA Time Weighted Average (TWA). Noise levels shall be determined in accordance with IEEE Standard #85, Test Procedure for Air-Borne Noise Measurements on Rotating Electric Equipment.

1.1.5.1 Horn and Strobe Systems in Mechanical Equipment Rooms

Mechanical equipment room NC curves may exceed the levels listed above with written permission from DEN Mechanical Engineer. To obtain written permission from DEN Mechanical Engineer, the Consultant must provide a comparison of all different equipment and strategies for reducing NC curves to the DEN Mechanical Engineer by the 60% Contract Document Submittal and a written explanation of why these alternatives were rejected. Cost premiums on more quiet equipment or sound masking shall not constitute a reason for rejection. If DEN accepts deviation from the above standards, a horn and strobe system may be used in mechanical equipment rooms only. The horn and strobe shall be installed per the most recent edition of NFPA 72.

1.1.6 Altitude Correction

The design of all air systems, gas-fired equipment, and other affected mechanical equipment shall incorporate an adjustment for the altitude at DEN of 5,400 feet above sea level. The following parameters for altitude conditions are:

A. Relative density correction factor = 0.819
B. Air density = 0.0614 lbs/cu.ft
C. CFM transfer factor = 0.884

1.1.7 Supports and Penetrations

All supports and anchors for mechanical and plumbing equipment shall be designed, detailed, and specified by a Colorado-licensed Structural Engineer. Provide detail including how attachment is to be made, i.e., between roof curb and equipment as well as roof curb and roof structure. A specification section is not sufficient for detailing any connections. Support sizing by the contractor is prohibited.

In general, cable and/or wire supports are not allowed.

Penetrations and reinforcement of penetrations through structural floors and/or walls shall be designed, detailed, and specified by a Colorado-licensed Structural Engineer.

1.2 Equipment Identification

1.2.1 General

All mechanical and plumbing equipment shall have a unique equipment designation. As of 2014, DEN modified the original scheme for tagging all assets.

These new naming conventions standardize the naming and numbering of all DEN mechanical and plumbing equipment. All DEN mechanical and plumbing equipment shall contain a numbering system according to the criteria outlined below. Any deviation from the naming convention must receive written approval from the DEN mechanical engineer before implementation. The naming convention outlined below should be fully coordinated with the requirements of tagging in the BIM model. Refer to the DFI DSM.

1.2.2 Air Handling Unit, Unitary Equipment, and Hydronic Equipment Identification

The components used to identify large equipment, such as Air Handling Units (AHUs), and unitary equipment, such as Unit Heaters (UHs), Cabinet Unit Heaters (CUHs), and Fan Coil Units (FCUs), depend on the location and requirements of the project. The DEN naming system consists of five standard components and one optional component, as follows.

LLL	_	NN	_	NL	_	LLL	_	L	_	NN
(1)		(2)		(3)		(4)		(5*)		(6**)

L = Alphabetical character

N = Numerical character

** = Only used for AHUs*

** = Only used for Unitary Equipment

1.2.2.1 Building Abbreviation

The three-character abbreviation for each building shall be used to designate the location of equipment. This abbreviation is assigned by DEN, for example: TML = Terminal, AOB = Airport Office Building, CCx = Concourse x, where x is the alpha designation of the concourse, e.g., A, B, C, etc.

CCB	_	04	_	7W	_	AHU	_	A	_	

1.2.2.2 Building Level

The building level is a two-digit indicator used to further refine the location of equipment. This abbreviation is assigned by DEN, for example: 00 is the Basement Level, 02 is the Concourse Level, etc.

CCB	_	04	_	7W	_	AHU	_	A	_	

1.2.2.3 Building Module

The building module is a two-digit designator that combines the building module and direction. It shall be used to further refine the location of equipment. This abbreviation is assigned by DEN, for example: 3W is module 3 West.

CCB	_	04	_	7W	_	AHU	_	A	_	

1.2.2.4 Equipment Abbreviation

Equipment abbreviations are assigned by DEN and are listed in Table 1-3: Equipment Abbreviations.

CCB	_	04	_	7W	_	AHU	_	A	_	

1.2.2.5 Concourse AHU Alphabetical Designator

AHUs in the Concourses are identified by an alphabetical designator (a letter). Generally, AHU-As serve holdroom, subcore, and center core perimeter zones, AHU-Bs serve holdroom, subcore, and center core interior zones, AHU-Cs serve holdroom conveyances, and letters beyond C are used for other various zones. Refer to Concourse AHU zoning details for zones existing AHUs serve. In general, Designers should try to replicate existing AHU zones when designing new buildings or expansions.

Each building module must only have one AHU of each designation (e.g., module 7W cannot have two AHU-As in it).

CCB	_	04	_	7W	_	AHU	_	A	_	

1.2.2.6 Numeric Designator

The numeric designator shall produce a unique identifier that belongs to only one piece of equipment. The numeric designator ranges from 01 – 99, where a placeholder of zero will be utilized for values less than 10. This is to be unique for each room unless replicated somewhere else. In the Concourses, this designation is only used for non-AHU unitary and hydronic equipment at DEN, such as FCUs and pumps. In the Terminal, Hotel, AOB, and outlying buildings, AHUs are also designated numerically 01 – 99 within the building (e.g. in the Terminal, there is only one AHU with the Equipment Abbreviation and Numeric Designator combination AHU_01).

CCB	_	04	_	7W	_	AHU	_	A	_	09

1.2.3 Dependent Unit Equipment Identifier

Due to the sheer number of terminal units at DEN (e.g., terminal devices such as VAVs, ATs, and FPBs), additional information must be included to ensure each equipment name is unique. Points for terminal equipment will have a naming component identifying the equipment that serves them inserted as follows. This naming convention shall also be used for split-system DX cooling and heat pumps where applicable. Any split system air conditioner and/or heat pump shall include the dependency identifier for both pieces of equipment.

LLL	_	NN	_	NL	_	LLL	_	XXXLL L (LL)	_	NN
(1)		(2)		(3)		(4)		(5)		(6)

1.2.3.1 Building Abbreviation

The three-character abbreviation for each building shall be used to designate the location of equipment. This abbreviation is assigned by DEN, for example: TML = Terminal, AOB = Airport Office Building, CCx = Concourse x, where x is the alpha designation of the concourse, e.g., A, B, C, etc.

CCB	_	03	_	6E	_	VAV	_	07WAB	_	OSH

1.2.3.2 Building Level

The building level is a two-digit indicator used to further refine the location of equipment. This abbreviation is assigned by DEN, for example: 00 is the Basement Level, 02 is the Concourse Level, etc.

CCB	_	03	_	6E	_	VAV	_	07WAB	_	OSH

1.2.3.3 Building Module

The building module is a two-digit designator that combines the building module and direction. It shall be used to further refine the location of equipment. This abbreviation is assigned by DEN, for example: 3W is module 3 West.

CCB	_	03	_	6E	_	VAV	_	07WAB	_	OSH

1.2.3.4 Equipment Abbreviation

Equipment abbreviations are assigned by DEN and are listed in Table 1-3: Equipment Abbreviations.

CCB	_	03	_	6E	_	VAV	_	07WAB	_	OSH

1.2.3.5 Dependency Identifier

This series of numbers and letters is an abbreviated version of the parent unit's equipment name and represents the AHU, coil section, or condensing unit that serves the terminal unit or the other half of the split system. The first two numbers in the abbreviation represent the floor the AHU is on (in the example below, 04 represents the fourth floor). The third number and the first letter represent the building module where the AHU is located (in the example below, 7W represents holdroom 7 west). The final letters represent the equipment type and equipment identifier (in the example below, AB represents AHU-B). For an air-cooled condensing unit, these last letters would be ACU##. For a fan coil unit that includes the DX cooling coils, the last letters would be FCU##. Thus, an ACU as the parent equipment would have the FCU as a dependent, and an FCU as the parent equipment would have the ACU as a dependent.

CCB	_	03	_	6E	_	VAV	_	07WAB	_	OSH

1.2.3.6 Numeric Designator

The numeric designator shall produce a unique identifier that belongs to only one piece of equipment. The numeric designator ranges from 01 – 99, where a placeholder of zero will be utilized for values less than 10. This is to be unique for each room unless replicated somewhere else. For terminal units with heating (e.g., a VAV box with reheat), an H shall be added to the end of the numeric designator.

CCB	_	**03**	_	**6E**	_	**VAV**	_	**07WAB**	_	**OSH**

1.3 DEN Mechanical/Plumbing Equipment Naming Components – Identifiers

The following table provides the identifiers and their descriptions for use in equipment naming conventions.

Table 1-3: Equipment Abbreviations

Identifier	Description	Identifier	Description
AC	Air Compressor	GWH	Gas Water Heater
ACU	Air Conditioning Unit (CRAC)	HRC	Heat Recovery Coil
ADS	Air/Solid Separator	HRP	High Resolution Pump
AHU	Air Handling Unit	HSC	Horizontal Split Case Pump
AS	Air Separator	HWP	Heating Water Pump
B	Boiler	HX	Heat Exchanger
C	Chiller	IRH	Gas Infrared Heater
CRAC	Computer Room Air Conditioner	MAU	Makeup Air Handling Unit
CT	Cooling Tower	P	Pump
CUH	Cabinet Unit Heater	PCA	Pre-conditioned Air Handler
CHWP	Chilled Water Pump	PWC	Potable Water Closet
CV	Control Valve	PCU	Pollution Control Unit (Scrubber)
DWP	Domestic Water Pump	RAF	Return Air Fan
EBB	Electric Baseboard Heater	RHC	Reheat Coil Unit
EF	Exhaust Fan	RTU	Roof-Top Air Handling Unit
EIH	Electric Infrared Heater	SF	Supply Fan
EMCS	Energy Management Control System	SG	Slide Gate
ET	Expansion Tank	SP	Sump Pump
EUH	Electric Unit Heater	TP	Transfer Pump
EWH	Electric Water Heater	UH	Unit Heater
FCU	Fan Coil Unit with Heating and Cooling Coil	VAV or AT	Variable Air Volume Box (Terminal Unit). Note that AT is for historical reference only, no new units shall be called AT

Table 1-3: Equipment Abbreviations (Continued)

Identifier	Description	Identifier	Description
FCU-DX	Fan Coil Unit with DX Cooling	VAV-H or ATH	Variable Air Volume Box with Heating Coil (Terminal Unit with Heating). Note that ATH is for historical reference only, no new units shall be called ATH
FCU-H	Fan Coil Unit with Heating Coil	VFD	Variable Frequency Drive
FPVAV	Fan-Powered Variable Air Volume Box	VLT	Vault Supply Fan System
F-SE	Smoke Exhaust Fan	VSCF	Ventilation Smoke Control Fan (Historical Reference Only)
FTR	Fin-tube Radiator	WG	Waste Disposal Grinder (Triturator)
GR	Open Channel Grinder	WH	Water Heater
GV	Gate Valve		

1.4 Submittals

1.4.1 Design Submittals

Regardless of the requirements outlined by the Design Analysis Report, or lack of, the Designer shall submit the following electronic files at the 100% phase of the project to the DEN Project Manager:

A. Space load calculations
B. Ventilation calculations defined by the latest version of ASHRAE 62.1
C. Equipment sizing and selection (AHU, MAU, FCU, Pump, Expansion tank, water heater, etc.)
D. Duct sizing and static pressure analysis
E. Hydronic piping sizing and static pressure analysis
F. Plumbing piping sizing and code analysis
G. Building pressurization analysis
H. Smoke Control Analysis
I. Energy Analysis
J. Tenant airflow requirements (if required)
K. Additional calculations, as requested by DEN Design, Engineering, and Construction
L. Cut sheets of all equipment selected and labeled to match scheduled equipment tags. Identify any nuances to the equipment for reviewers to be aware of.

Each item shall be included as a single, book-marked PDF file. No paper copies are required or will be accepted. All equipment shall be labeled as identified on the contract drawings. Each filename should include the contract number.

Refer to the Digital Facilities and Infrastructure Design Standards Manual and the Standards and Criteria Design Standards Manual for additional design submittal requirements.

1.4.2 As-Built Submittals

The Designer shall submit electronically through the DEN Project Manager the information outlined in 1.4 Submittals with corrections made due to field changes in construction.

Refer to the Digital Facilities and Infrastructure Design Standards Manual for additional as-built submittal requirements.

1.5 Equipment Supports and Thermal Expansion Compensation

1.5.1 Design

All equipment supports and thermal expansion compensation shall be manufactured systems or designed and detailed by a Colorado Registered Professional Engineer. Supports shall be coordinated with Architectural and Structural disciplines. Under no circumstances shall the construction documents direct a Contractor to provide supports without detailed performance specifications outlining the criteria and requirements of supports and their design and installation.

End of Chapter

Chapter 2 - Central Utility Plant

2.0 Central Utility Plant

2.0.1 Existing Campus Heating/Cooling Systems Operation

Chilled water and heating water for the HVAC systems in the terminal buildings, HTC, AOB, and concourses are supplied from the Central Utility Plant (CUP).

A. Heating water is provided by hot water generators consisting of one (1) 62,500 MBH main boiler and six (6) 20,000 MBH boilers. In 2024, work will begin to replace the existing 62,500 MBH boiler with two (2) 20,000 MBH boilers.

B. Chilled water is produced by eight (8) 2,500-ton variable speed centrifugal chillers that consist of two (2) compressors each.

The hot water and chilled water systems consist of boiler and chiller primary distribution piping loops located in the CUP and the utility tunnels below the AGTS tunnel.

A. The primary distribution piping supplies the variable speed secondary loop pumps located at the terminal, AOB, Hotel Transit Center, and the three (3) concourses (the 6 main zones).

B. The variable speed secondary pumps deliver water to the loads, which consist of coils in the air handling units (AHU), Variable Air Volume (VAV) systems, fan-powered boxes, and other terminal air devices. Each secondary loop consists of pumps in parallel supplying a variable flow as required to maintain static pressure setpoint in the critical hydraulic circuit of each zone loop.

All main AHU coil flows are modulated with 2-way pressure-independent control valves.

An energy management system (the CUP EMCS) controls the water supply temperature in the primary loop and controls the flow and pressure relationships between the primary loop and the secondary loops to match the load.

A. The primary hot water discharge temperature from the boilers and in the primary loop is variable between 200°F and 230°F that is controlled by a reset schedule. Control valves at the secondary loops then mix the hot water temperature down to 190°F for distribution to the secondary zones.

B. During the cooling seasons, when the Chiller compressors are energized, the secondary chilled water supply temperature is 40°F± (although this can vary). Chilled water supply temperature can be reset up to a maximum of 48°F under non-peak loading conditions.

C. When the refrigeration load decreases because of lower outside temperatures during the fall, winter, and spring seasons, the cooling mode utilized is the free cooling system using plate and frame heat exchangers (PHEs).

In the free cooling mode, the chillers are bypassed, and the condenser water is pumped from the 322,500-gallon sump through the plate and frame heat exchanger that cools the chilled water. A minimum of two cooling towers run during this time. The system changeover to free cooling mode is selectable at the EMCS terminal. Changeover to the PHEs is not instantaneous due to the amount of time it takes for the sump temperature to stabilize. The manual changeover to free cooling occurs when outdoor air temperatures do not rise above 60°F to 65°F and chilled water supply temperature can be maintained below 48°F±. On a further increase in demand when the chilled water rises to 48°F±, the heat exchangers will be bypassed, and additional cooling towers and chillers will come on sequentially.

As of 2013, the sump was separated into two sections. The two sections are connected or isolated using a series of automated slide gates. This allows several operational modes that were previously unavailable, such as isolating a section of the sump for maintenance and operating the sump/condenser water system at dual temperatures for transition between mechanical and PHE cooling in the shoulder seasons.

In 2013 and 2014, the CUP underwent a major controls renovation and upgrade. A centralized Johnson Controls Metasys EMCS was installed to supervise the control of all equipment, pumps, and control valves. Controllers and/or operational sequences are being updated for most CUP systems, and the Optimum Energy CPO30 system is being installed to manage chiller plant energy performance.

Historical Reference: The current configuration and description differ from the original CUP design. The original design featured three sets of pumps that hydronic water passed through before reaching loads. The legacy configuration was as follows:

A. The plant distribution pumps, variable volume transport-primary pumps (for the five main zones), and constant volume user-secondary pumps were located throughout the terminal complex.
B. Due to major hydronic optimization and controls retrofit projects, the old user-secondary pumps have been removed throughout, and the hydronic system has been converted to a primary-secondary arrangement (no tertiary pumps as before).
C. The old plant distribution pumps have been renamed the primary pumps, and the old variable volume transport-primary pumps have been renamed the secondary pumps, as described in the preceding paragraph.
D. The decoupler line between the secondary and primary loops remains but is no longer used for differential pressure control. It is used for primary loop pressure relief and will open if the differential pressure raises in the system too much.
E. The legacy BRDG-TNDR (Bridge Tender) controls have been removed.

2.0.2 Seasonal Operation

The heating and chilled water systems do not run continuously throughout the year. In general, the heating plant is offline from May 15 to September 15. The chilled water system runs without chillers in a free cooling mode from November 15 to March 15. Weather plays an important scheduling factor in the operations of these systems. Typically, when average daily temperatures drop below 50°F, the boiler plant is operational. When average daily temperatures are above 60°F, the chiller plant is operational and not running in a free cooling mode.

2.1 Equipment

2.1.1 Chillers

The final chiller selection and sizing shall be determined based on refined load calculations and profiles. The chillers shall be open drive, centrifugal type, using a refrigerant not currently listed by the United Nations Environmental Program Montreal Protocol for production and consumption limitations. The CUP includes eight (8) nominal 2,500-ton chillers using R-123 refrigerant. All chiller prime movers for new machines shall be electric-driven and variable speed. Chillers shall have a maximum energy consumption of 0.60 kW/ton at design conditions. Chillers should be selected based on a lifecycle cost analysis.

Cooling plant design shall provide sufficient space and equipment support for adding future capacity of at least two additional chillers of the larger percent capacity range.

Table 2-1: Chiller Design Parameters

Parameter	Temperature
Chiller entering chilled water temperature	56°F
Chiller leaving chilled water temperature	40°F
Chiller entering condenser water temperature	71°F
Chiller leaving condenser water temperature	81°F

Chillers shall be provided and rated in accordance with ARI-550-88 (or the latest addition) and the latest edition of ASHRAE standards 30 and 90.1. Large chillers shall be provided with a free cooling option that consists of piping and valves, which permit the use of reduced condenser water temperature for cooling via thermally migrating refrigerant.

Chillers shall be furnished and piped in such a manner as to provide easy access to the tube bundles for cleaning. The chiller machine motor, gear drive, and compressor shall be mounted on a common base to ensure shaft alignment.

The chillers shall be provided with controls to modulate the chiller operating capacity to match load or as required by the CUP EMCS. The chillers shall be provided with all safety controls, limits, interlocks, and accessory devices to maintain efficient, safe operation per the manufacturer's recommendations.

In addition to the migrating refrigerant-free cooling option mentioned earlier, a waterside economizer (plate frame heat exchanger utilizing tower water), piping, valves, and controls for mild weather-free cooling shall be provided. The heat exchangers shall cool water in the chilled water system from sub-cooled condenser water. Installation shall allow for all maintenance and servicing clearances. Construction documents shall indicate all servicing and maintenance clearances required.

Absorption chillers may be used in the CUP for waste heat recovery applications only.

2.1.2 Refrigerant Recovery

The chillers are directly connected to a common refrigerant transfer system for the containment of refrigerant. The system consists of a manual valve arrangement for each chiller with associated compressors capable of transferring R-123 refrigerant. The transfer system is commonly referred to as an RTU.

2.1.3 Cooling Towers

The cooling tower capacity shall be based on chiller selection, free cooling requirements, PCA, and other miscellaneous loads on the condenser water system. The cooling towers shall be architectural concrete tower exterior, counter-flow evaporative type cooling towers with induced air fans that operate at variable speeds (via VSD/VFDs). The selection shall be made to minimize energy consumption and initial cost and to provide for ease of maintenance. Alternate tower selections requiring less energy consumption shall be solicited from the construction contract bidders for review by DEN as to the suitability and cost savings. The final selection is to be made by DEN based on an evaluation by the Design Consultant.

Table 2-2: Cooling Tower Design Parameters

Parameter	Temperature/ Flow Rate
Chiller entering condenser water temperature	71°F
Chiller leaving condenser water temperature	81°F
Wet bulb temperature	64°F
Cell flow rate	6,500 GPM

The towers shall be provided with means of controlling tower capacity for mild and low ambient operation and with adequate means for winter operation without excessive ice buildup or damage to the tower. The towers and chillers shall be designed to take advantage of the large number of operating hours at low ambient conditions for indirect free cooling with condenser water temperatures reaching as low as 38°F. Tower water flow across each section or cell should be held constant during low ambient conditions.

The tower fill media shall have a 25-year life with a maximum temperature rise of 1°F in leaving water conditions over that life span. Fill shall be suitable for winter operation.

All towers shall be certified in accordance with Cooling Tower Institute Standard 201 Certification Standard for Water Cooling Towers or field tested in accordance with ASME Standard PTC23 or Cooling Tower Institute Bulletin ATC-105 to verify tower performance.

2.1.4 Boilers

The existing boiler plant currently contains six (6) 20,000 MBH boilers and one (1) 62,500 MBH main boiler. In 2015, Boiler #6 was added due to the failure of boiler #2. Boiler #6 is a steam boiler that converted hot water and runs off of natural gas. Due to current piping and pump limitations, its capacity is reduced to 52,000 MBH. The boiler is currently inoperable and is slated for demolition in the near future. In 2016, boiler #2 was replaced with three (3) 20,000 MBH boilers and piping and pump modifications. In 2023, boiler #1 and #3 were replaced with three (3) 20,000 MBH boiler and piping and pump modifications. It is anticipated that by the end 2024, the last large boiler will be replaced with two (2) 20,000 MBH boilers.

New boilers shall be provided with dual burners and controls and shall be fired on natural gas, with jet fuel (or light oil) as a standby fuel source. The boilers shall have a minimum efficiency of 80% fired on natural gas and shall be provided with combustion controls to maintain maximum combustion efficiency over the full burner modulating range.

The boiler burners shall be arranged for a high turndown ratio for improved operation at low firing rates. Ultra-Low-NOX burners shall be used with emissions at 15 ppm or less when firing on natural gas. Flue gas economizers shall not be used unless subsequent economic studies indicate that suitable cost savings could be realized. Flue gas recirculation shall be provided to minimize air pollution effects.

The boilers shall supply hot water to the hot water heating distribution piping system. The boiler plant is provided with treatment equipment to minimize corrosion and other detrimental effects on the boilers and piping system. Boiler safety devices shall be provided as required by the Denver Building Code and as recommended by ASME.

2.1.5 Pumps

Pumps shall be selected for maximum operating efficiency (i.e., slightly to the right of the maximum efficiency point on the pump curve). Single pumps to be used in throttling applications without variable speed drives shall have relatively flat performance curves and be selected for operation on the pump performance curve to the right of the point of highest efficiency. Multiple pumps for parallel operation shall have relatively steep performance curves. Multiple pumps for series operation shall have relatively flat performance curves. Pumps for variable speed drive applications shall have relatively steep performance curves. All pumps shall be specified with suction and discharge flange taps for pressure gauge connections.

The final selection of pump types and the application arrangement shall be made to maximize pump efficiency without excessive initial pump costs. All pumps that are selected for both current and future needs will be sized for future requirements, where practical, and equipped with the necessary accessories. In general, pumps shall be lead-lag with N+1 operational redundancy consideration. N+1 selection is required for critical operational equipment. The lower initial performance requirement will be met by balancing valves or using a trimmed impeller to provide energy-efficient operation in start-up performance.

Standby pumps and accessories shall be provided for both heating and cooling systems. Pumps shall be arranged in a parallel configuration and headered to maximize pumping flexibility.

In general, vertical turbine pumps shall be used for pumping cooling tower water. Hydronic water applications shall use end suction pumps for flow rates below 500 GPM. Horizontal split case: double suction pumps shall be used for flow rates above 500 GPM.

High-rpm pumps (>1750 rpm) should only be used when no other alternative exists.

All pumps in the heating water system shall be specified with components that are rated for 230°F continuous operation.

2.1.6 Air Compressors

The main control air compressors shall be the oil-free, screw type provided with regenerative air dryers. The final compressor capacity and storage volume shall be determined from the compressed air demands of the temperature controls, pneumatic operating door systems, and any other functions that require oil-free air.

The control compressed air system shall be designed for a compressed air main pressure of 100 psig. Air dryers shall dry the compressed air to a pressure dew point of-40°F. Regenerative or refrigeration-type systems shall be used. The regenerative air dryer shall be provided with an external heat source for drying element regeneration.

The control air compressor system shall be complete with an air-cooled after-cooler, storage tank, regenerative air dryer and coalescing, and particulate filters. The central compressed air system shall have full standby redundancy in the compressors, dryers, and after-coolers.

All main equipment rooms shall have quick-disconnect fittings and valves to facilitate using portable air compressors should the main control air compressor system fail.

Any shop air compressors may be lubricated reciprocating type for 100 psig and equipped with an aftercooler, storage tank, and inlet air filters. No regenerative or refrigerated air dryers are required.

2.1.7 Motors

Electric motors shall conform to NEMA Standards. All 3-phase motors shall be high-efficiency types. Motors shall not be selected for operation in the service factor range.

The minimum system installed power factor shall be 90%, with a goal to attain a 95% system power factor. Motors larger than 15 hp shall have power factor correction.

Motors shall be specified to be provided with adequate thermal protection, integral or external control, branch circuit protection, and starters suitable for use with the motors. Motor and starter types shall be selected to minimize voltage fluctuations and current surges. Motors and starters shall be provided with auxiliary contacts for control and operation interface with the central EMCS and any other control functions included.

2.1.8 Water Treatment

Chemical treatment systems shall be provided at the CUP for the protection of the chilled water, condenser water, and hot water systems from scale, corrosion, biological growths, and suspended solids.

Chemical treatment for the chilled and hot water systems shall include the use of a corrosion inhibitor. The water treatment for the condenser water system shall include blowdown, pH, and micro biocide control.

The services of a qualified water treatment specialist shall be used and specified for running tests on the water supply and the establishment and implementation of the water treatment programs for the CUP systems.

Water cleaning shall be accomplished by providing a strainer at the suction of each pump. In addition, a final strainer shall be installed downstream of the last system pump.

The chilled water and hot water systems use air-dirt separators on the main lines to remove debris in the piping system. There are centrifugal side stream filters on the main lines as backup. The condenser water systems shall each have a bypass sand filter installed.

2.1.9 HVAC

The CUP shall be provided with equipment to heat and ventilate the CUP equipment areas and to provide boiler room combustion air. Heating of ancillary spaces shall be provided with hot water unit heaters. Ventilation for summer heat relief in non-conditioned spaces shall be provided by the application of outside air louvers and exhaust fans. A minimum air change rate of 10 AC/HR shall be provided for summer. In addition, ventilation shall be provided for the sump to prevent stagnation and odor migration, and emergency exhaust shall be provided for equipment areas subject to possible refrigerant leakage.

The existing CUP main air handling systems are:

A. AHU-B1, B2, B3, and B4 – Boiler Room Combustion Air:
    a. 100% OSA
    b. Hydronic heat
    c. Constant volume

B. AHU-ER – Pump Room:
   a. Recirculation with economizer
   b. Hydronic heat/cool
   c. Constant volume
C. AHU-CR – Pump/Control Room:
   a. Recirculation with economizer
   b. Hydronic heat/cool
   c. Constant volume
D. AHU-C1, C2, and C3 – Chiller Room:
   a. Recirculation with economizer
   b. Hydronic heat/cool
   c. Constant Volume

The existing chiller room emergency exhaust fan is sized for 12 ACH.

2.1.10 Piping and Valves

Piping for both the CUP and the distribution systems shall be designed to minimize pressure losses and maximize energy use efficiency. Valves to be specified for equipment servicing shall be selected to minimize losses while open and have suitable pressure drop characteristics for the intended use. The piping shall be designed to allow for CUP equipment expansions.

Control valves shall be sized for the correct and appropriate Cv value at the design flow rate. All valves shall be suitable for extended service operation without extensive requirements for lubrication or servicing.

Tees, valves, and blind flanges shall be provided to allow for additions of equipment and piping to the CUP without interruption of services. Piping systems shall be sized for ultimate loads. Tees, valves, and blind flanges shall be provided on distribution piping systems for the expansion of distribution systems; sectional valves shall be provided in the distribution piping for piping system repairs and at key locations to provide isolation and servicing of equipment. On compressed air lines, quick disconnect connections shall be installed downstream of sectional valves to enable the use of portable compressors in emergencies. The piping design and materials selection shall be in accordance with ANSI/ASME Standard B31.9 Building Services and ANSI/ASME Standard B31. Power Piping.

The hydronic systems design shall be based upon the following criteria.

A. Piping shall be designed in accordance with specified technical criteria. Water pipe sizing shall be based on the stricter of the two following parameters:

Table 2-3: Water Piping Sizing

Pipe Size	Max Velocity (fps)	Max Pressure Drop* (ft per 100 ft pipe)
up to 2"	4	8.5
2-1/2" thru 6"	6	4
8" thru 12"	8.5	2.5
14" thru 20"	10.5 (14)**	2.5
24" thru 42"	11.0 (14)**	1.5

** Based on new, clean steel pipe*

** Number in parentheses is velocity limit applicable to long straight runs where noise is not critical (such as pipe tunnels, etc.). Maximum pressure drop still applies.

B. Pressure drops in piping systems shall be calculated to allow for aging and corrosion of the interior surface. Therefore, all water piping systems shall be designed with the following friction factors (C values) based on the Hazen Williams Friction Factor formula.

Table 2-4: Water Piping Friction Factors

System Type	C Value
Closed Water	120
Closed, treated water	130
Open water	100
(New clean steel pipe)	(140)

C. Hot and chilled water distribution systems should be designed for variable volume flow.

D. Hydronic systems should be designed for the widest practical ΔT and the closest possible approach of the return water temperature to the terminal equipment supply air temperature.

E. The terminal equipment must be selected not only for its full load capacity but also for its performance over the full range of partial loads. Laminar fluid flow in the coils shall be avoided.

F. Integral face and bypass coils should be utilized with preheat coils.

G. Coils subject to 100% outside air at winter design conditions shall be protected by one of the following methods:

   a. Provide propylene glycol in the water loop serving the AHU coils for those units arranged for smoke removal- automatic 100% outside air capacity. These units must not be equipped with protective override controls to shut off the fan if a freezing condition is determined when operating for smoke removal. The glycol-water loop for this system is to be linked to the main heating hot water system through a plate and frame-type heat exchanger.
   b. For those units not arranged for smoke removal use, provide freeze protection thermostats on the coil face to shut down the unit fan if a freezing condition is detected.

H. The impact of the change in volume due to the thermal expansion of the distribution system fluids during all operations must be addressed in the design process.

I. Control valves in hydronic systems must not be oversized. The flow characteristics and pressure drops are to be selected for the appropriate Cv value corresponding to the design flow to be controlled.

J. Provide automatic air vents at all coils and at the high points of all piping. Provide drains at the low points of all piping.

K. Hydronic systems controls shall be automatic and adjustable to optimize pumping and thermal efficiency.

   a. As of 2012, three-way valves are no longer allowed at DEN at the terminal complex.
   b. Use pressure-independent two-way valves at coils in variable flow systems.
   c. Hot water coil valves shall fail to the open position.
   d. All valves in the heating water system shall be specified with components that are rated for 230°F continuous operations.

2.1.11 Central Plant Facilities

The CUP facilities include toilets, equipment operator areas, maintenance personnel offices, a control room, CUP EMCS/legacy EMCS control stations, and spare parts tool and inventory areas. The CUP houses:

A. Chillers

B. Chiller pumps

C. Chilled water primary distribution pumps

D. Boilers
E. Hot water pumps
F. Cooling tower and pumps
G. Water treatment equipment
H. Water treatment chemicals
I. Air compressors
J. Compressed air aftercoolers
K. Compressed air dryers
L. Compressed air storage tank and the associated piping and valves for the chilled water, condenser water, hot water, and compressed air systems
M. Miscellaneous equipment

Each water distribution system shall be designed to maximize system and equipment performance and minimize energy usage under all load conditions throughout the system's seasonal operation. The system must also provide the required water flow to and from all load points under all system load conditions. The following proposed system configurations describe a means to accomplish the system objectives. However, the final system configuration and layout should be determined based on the actual equipment capacities and sizes and system requirements. The chilled water, hot water, and condenser water system configurations should be refined and finally established when the final system parameters are determined.

2.1.12 Chilled Water System

The chilled water system shall be configured in a primary-secondary arrangement. The first loop is the primary loop, which shall use chiller pumps in parallel and headered to circulate water through the chillers that are piped in parallel.

The pumps shall be connected in parallel on suction and discharge headers with a 1-to-1 ratio of chiller pumps to chillers. Pumps shall modulate speed to maintain flow through the operating chillers and around the primary loop. Under no circumstances shall the chilled water pumps deliver flow below the minimum allowable flow to an operating chiller. The chiller loop must be arranged to easily adapt additional chillers and chiller pumps for future capacity requirements.

The distribution loops are labeled secondary loops and are variable flow systems. The primary loop distributes the chilled water from the chillers to the terminal building, concourses, and other buildings and areas to be served with cooling, where secondary pumps in parallel supply the secondary distribution piping with chilled water.

The secondary pumps shall be modulated and staged based on static pressure at the most hydraulically remote point of the critical circuit of each secondary distribution loop. The CUP EMCS shall cycle the primary loop pumps to match the combined system load of the secondary loops by maintaining a slight positive flow (approximately 1–2%) in the decoupler line between the primary and secondary loops.

Flow measuring devices are required in each loop and subcircuit, as well as in the decoupler.

2.1.12.1 As-Built Drawing Chilled Water Abbreviation

Existing drawings for much of DEN denote the Chilled Water Supply and Chilled Water Return abbreviations as CWS and CWR, respectively. New drawing sets shall use industry-standard abbreviations for Chilled Water Supply and Chilled Water Return: CHWS and CHWR, respectively. CWS and CWR shall be used to denote Condenser Water Supply and Condenser Water Return, respectively.

2.1.13 Condenser Water System

The condenser water system shall be arranged with vertical turbine pumps, piped in parallel to supply condenser water from the sump to the chillers that are also piped in parallel. Each chiller also has its own dedicated condenser water pump upstream, with control valves and piping arrangements that provide several bypass options. When the condenser water leaves the chillers, it is routed to the cooling towers for heat rejection.

The condenser water system shall be provided with the necessary accessory piping, valves, controls, and equipment for the utilization of free cooling directly as part of the chiller equipment or provided through a separate heat exchanger.

The 2013 sump separation project introduced significant changes to the operations of the sump, cooling towers, and pumps (collectively, the condenser water system). The ability to isolate the sump into halves creates the possibility for seven (7) distinct operating modes:

A. Mechanical cooling with no sump separation.
   a. Normal summer/hot season mechanical cooling mode.
   b. All chillers and cooling towers are enabled.
   c. The only mode that achieves maximum chiller plant capacity.
B. Mechanical cooling with west sump isolation (West sump is full; East is unavailable).
   a. Used if sump maintenance is required during mechanical cooling operation.
   b. Limited to 39,000 GPM maximum condenser water flow to isolated sump section.
   c. Maximum six of the eight existing cooling tower cells (75% of max condenser load).
C. Mechanical cooling with east sump isolation (East Sump is full; West is unavailable).
   a. Used if sump maintenance is required during mechanical cooling operation.
   b. Limited to 26,000 GPM maximum condenser water flow to isolated sump section.
   c. Maximum four of the eight existing cooling tower cells (50% of max condenser load).
D. Plate Frame HX-free cooling mode with no sump separation.
   a. The following sequences are implemented in the CUP for the free cooling mode of operation:
      1. Plate and frame exchanger 3 is the default exchanger.
      2. Plate and frame exchangers 1 and 2 now have a single toggle on the new “Plate N Frame” graphics to enable or disable them when the system is in Free Cooling mode.
   b. Condenser water pumps control to maintain 34 PSI in the condenser water header.
   c. Chilled water pumps control to maintain a positive 50 GPM through the decoupler.
   d. Normal winter/cold season free cooling mode.
   e. Maximum four cooling tower cells operated simultaneously for PHE-free cooling (14,260 GPM).
   f. Cooling Tower activation shall be staged based on outside air temperature (OAT):
      1. Upon a fall in temperature below 38°F OAT, four (4) Towers shall run.
      2. Upon a fall in temperature below 36°F OAT, three (3) Towers shall run.
      3. Upon a fall in temperature below 33°F OAT, two (2) Towers shall run.
      4. Upon a fall in temperature below 24°F OAT, one (1) Tower shall run.
      5. At any OAT below 24°F, only one cooling tower shall run to prevent towers from icing.
      6. Upon a rise in temperature above 28°F OAT, two (2) Towers shall run.
      7. Upon a rise in temperature above 35°F OAT, three (3) Towers shall run.
      8. Upon a rise in temperature below 38°F OAT, four (4) Towers shall run.
E. Plate Frame HX free cooling mode with west isolation.
   a. Used for sump maintenance during PHE-free cooling operation.

      NOTE: Sump maintenance will take place primarily during the cold season.

   b. Turbine pumps serving isolated sump modulate/stage to provide condenser flow and a pressure of 34 PSI in the header.
   c. Only towers in cells 2 – 5 shall be used.
F. Plate Frame HX free cooling mode with east isolation.
   a. Used for sump maintenance during PHE-free cooling operation.

      NOTE: Sump maintenance will take place primarily during the cold season.

b. Turbine pumps serving isolated sump modulate/stage to provide condenser flow and a pressure of 34 PSI in the headers.
c. Only towers in cells 6 – 9 shall be used.

G. Transition mode with sump separation but no isolation
   a. Normal shoulder season transition mode with full PHE and partial chiller capacity available (not simultaneously).
   b. Sump, respective cooling tower banks, and the 48" CS header are completely separated.
   c. Resulting in a dual-temperature condenser system that independently serves the PHEs and chillers.
   d. Limited to 26,000 GPM maximum condenser water flow to East sump section; maximum four cooling tower cells available for chillers (50% of max condenser load.)
   e. CT-5 is not available in this mode.

2.1.14 Heating System

Heating in all building spaces shall be provided by hot water from hot water generators (boilers) located in the CUP. The hot water system will consist of a variable flow, primary hot water distribution system loop from the boilers to the Terminal Complex, and a secondary variable flow distribution system loop serving each building within the complex. The boilers are fed return water from a common header piping system that the primary pumps pump into. Primary hot water boiler pumps shall be equal in number to the boilers plus two spares (N+2) and shall circulate and maintain a constant temperature at each boiler outlet. The primary loop will consist of pumps in parallel supplying a variable flow at a constant temperature of 220°F (reset with outside temperature), as required by demand from the secondary loops. The primary pumps shall be modulated to match the total system load, which is the combined load of the secondary loops. Primary pumps are controlled to maintain a pressure differential setpoint at the end of the mains serving the concourses.

Each concourse and major facility adjacent to the CUP shall have its own secondary loop. Pumps serving the secondary loops shall provide a variable flow sufficient to maintain a pressure differential setpoint in the most hydraulically remote point on the critical circuit of the secondary loop. The concourses have several different sets of piping mains supplying different sections of the concourse and can control to different setpoints depending on the load distribution. The hot water supply temperature to each secondary distribution loop is maintained at a constant 190°F using a bypass across the secondary supply and return with a modulating control valve. This valve blends the 220°F water entering from the primary loop with the cooler (~150°F) return water to maintain the supply water temperature to the secondary zone. The return water temperature back to the primary loop can fluctuate, but under design conditions, should be 150°F. Designers shall provide one stand-by pump for each loop system.

Any work done on the boilers or heating water distribution system throughout the Terminal Complex is generally done during the summer months. The Hotel requires heating from the CUP year-round, and any heating system work must keep heating water supplied to the Hotel from either a temporary bypass or another temporary means depending on the type of work.

2.1.14.1 Hotel As-Built Drawing Heating Water Abbreviation

The Hotel/Transit Center (HTC) as-built drawings use a different abbreviation system for hot water than the rest of the Airport. HTC as-built drawings abbreviate the Heating Water Supply and Return as MTWS and MTWR. Because the HTC heating water hydronic system is fed by the CUP, the water temperatures of the HTC heating water hydronic system never exceed those in the primary hydronic loop.

2.2 Energy Management

2.2.1 General

Part of the 2013 CUP controls upgrade included the installation, via JCI, of the Optimum Energy CPO30 chiller plant optimization platform. This platform, which piggybacks off the CUP EMCS, is used to optimize the energy performance of the entire chiller plant by automatically adjusting setpoints and monitoring components and total system energy usage. The chiller plant will run primarily in this loop mode, with CPO30 providing setpoints and commands to the CUP EMCS (within certain pre-specified limitations). Secondarily, and as a backup, the chiller plant can be run in JCI mode according to the default JCI control sequences, which are designed to meet loads and safely operate all equipment but are not necessarily optimized for energy performance.

Previously, in 2009, an energy management system (Honeywell Energy Manager) was installed to monitor the energy usage of the chillers. This system connects to the Facilities EMCS (Honeywell EBI). This system will remain in place and will feed data to the new CUP EMCS.

2.3 Equipment Tags and Re-Numbering

In 2012, some equipment and essentially all pumps and control valves were renamed to follow a standard convention throughout the plant. Legacy ID tags are no longer used for these items. Please contact DEN Mechanical Engineer for the current naming schedule, which indicates new tags to be used for all current and future projects, as well as legacy ID tags for reference.

End of Chapter

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Chapter 3 - HVAC Systems

3.0 HVAC Systems

3.0.1 Air Handling Systems

The most appropriate designs for an airport terminal necessitate that the space conditioning system be flexible and responsive to wide swings in thermal loads. Factors include constantly changing people loads, high people door usage, air infiltration, shifting passenger densities, shifting solar loads, and baggage handling transfers in and out of the building. These items change in timing and intensity depending on changes in aircraft schedules and special peak passenger periods.

The air handling systems, including fans, motors, and duct static pressure losses, shall be adjusted for the high altitude at the airport site.

The AHU selection must also consider the primary system design. For DEN, the AHUs will utilize hot and chilled water from a four-pipe distribution system. Separate cooling and heating coils shall be required. The heating coils shall be selected for a minimum 40°F temperature differential (190°F to 150°F, plus or minus). The cooling coils shall be selected for an approximate 16°F temperature differential (42°F to 58°F, plus or minus 2°F) or as required by the psychometrics of the specific system design. This criterion shall be coordinated with the CUP design.

Packaged AHUs should be used for applications below 10,000 CFM. Customized, built-up AHUs may be used in applications above 10,000 CFM.

Cooling and heating coils are to be sized and arranged for water velocities in the 6 fps range. Air cooling coils shall be designed to have a maximum air face velocity of 600 fpm. Air heating coils shall have a maximum air face velocity not to exceed 800 fpm. Fin spacing shall be as wide as possible to provide the specified leaving coil conditions.

DX cooling coils shall be row split (in lieu of face split) where multiple coil sections are required. All refrigerants used at DEN shall be hydrofluorocarbons (HFCs) or HFC blends with a global warming potential (GWP) of less than 1800 and a refrigerant class A1 according to ISO 817. Other refrigerants not banned or phased out by the Montreal Protocol and amendments may be used only with written permission from DEN Mechanical Engineer.

Natural gas-fired heating coils shall be indirectly fired. Direct-fired heating coils shall only be used with written permission from DEN Mechanical Engineer. See 3.6 Sustainability for the use of natural gas-fired equipment at DEN.

All supply AHUs shall be draw-through, built-up systems except in instances where sound control would favor the application of blow-through units. Each unit shall consist of a non-overloading supply air fan selected for maximum efficiency. Fan selection shall be based on noise criteria requirements. Centrifugal fans shall be used; however, vane-axial fans may be considered if economy, efficiency, and noise criteria parameters can be assured.

In addition, each AHU system shall contain separate cooling and heating coils (includes cooling only units), a final filter section, a throwaway filter section, an air blender section to eliminate air stratification, a mixed air plenum for outside air and return air duct damper connections, and a sound attenuation section if required. Integral face and bypass dampers shall be considered for preheating coils in appropriate areas. Each AHU section shall be provided with an access door and non-breakable plenum light (coordinate with corresponding electrical designs). Heating coils shall be located upstream of the cooling coils, with space in between the two coil sections to facilitate access for maintenance and inspection. Tight shutoff-type dampers shall be provided for the outside air damper.

The following air handling systems may be used for various applications at the DEN terminal, concourse areas, and other support facilities. These include single-zone systems, Multi-zone systems, variable volume systems, heat pump systems, and rooftop HVAC systems.

3.0.1.1 Air-Handling Unit Access Doors

Walk-in access doors shall be installed in Air Handling Units to provide access for maintenance at every fan, damper, filter, coil, and sensor. Doors shall be sufficiently sized to allow for any motor, coil, filter, and/or damper to be removed from the unit without disassembling the unit’s frame or walls. Doors shall be mounted flush to unit walls and shall not compromise structural or thermal performance. Doors shall be hinged and, when open, shall not impede the removal of internal unit components such as motors, fans, or coils from the unit. Doors large enough shall have a 12x12 inch inspection window constructed of ¼ inch thick plexiglass.

Doors shall not limit any other maintenance requirements in this Design Standards Manual.

3.0.2 Single-Zone Systems

Single-zone type air handling systems will effectively handle any local area (zone) of a facility. However, a multitude of different temperature zones may necessitate a high number of single-zone AHUs. The disadvantages of such a design would be the requirement for more mechanical room space, higher maintenance costs, and increased capital costs due to the number of individual units that would be required. The use of single-zone AHUs on a large scale is not economical. A multitude of single-zone units serving large main spaces would also reduce the flexibility required to accommodate future space modifications.

Single-zone AHUs do have suitable applications; however, to serve certain perimeter zones of the terminal building and concourses. They also have applications in many areas in the various support facilities, where their use would prove to be the most suitable solution.

3.0.3 Multi-Zone Systems

Multi-zone air handling systems offer the advantage of centralizing air handling equipment to an extent; however, the use of this equipment is not an energy-efficient alternative. This is due to the constant mixing of heated and cooled air that could create a situation where the cost of distribution ductwork could exceed that of other alternatives. In addition, multi-zone units operate most of the time in a partial reheat mode (the air is cooled and dehumidified and then warmed, thus the term reheat). This is an energy waste that cannot be reconciled with current energy standards of the Model Energy Code and ASHRAE standard 90.1. Multi-zone units do not offer the flexibility desirable in airports for future space modifications.

Multi-zone units shall not be utilized in the design of DEN, its terminal, or concourses. Multi-zone units should be used only in unusual situations in remote facilities where only a few zones are required, and the economics justify their use.

Dual duct systems are similar to multi-zone systems in that both systems have a hot and cold deck. Constant volume dual duct systems will not be permitted. VAV dual duct systems, where there is no mixing of the hot and cold decks, are NOT an acceptable system for an application at DEN.

3.0.4 Heat-Pump Systems

Air-source heat pumps are not recommended for application in non-net-zero-energy facilities due to the predominately cooler climate of Denver, Colorado. Nearly 40% of the heating hours in Denver are below 30°F. At approximately 30°F and below, air-source heat pumps no longer function efficiently, and some other form of auxiliary heating is required.

Reverse cycle chiller-type heat pump systems and Variable Refrigerant Flow (VRF) systems may be used in any building at DEN designed for net-zero-energy usage. When designing these systems, designers must submit a life cycle cost analysis over the baseline of electrical resistance heating, along with any other systems considered for energy reduction measures during the schematic design phase. Where these systems are used, supplemental heating is required.

Air-source heat pumps may be used in very remote facilities where economic evaluations justify such systems. In these cases, supplemental heating is required.

3.0.4.1 Ground-Source Heat Pumps

Ground-source heat pump systems may be used for newly constructed buildings. Design of ground-source heat pumps must not require currently installed apron, taxiway, or runway panels to be demolished during construction. No ground-source heat pumps may be installed under movement area taxiways or runways. When designing ground-source heat pumps for a non-net-zero energy building, designers must submit a life cycle cost analysis over baseline hydronic heating or natural gas heating where hydronic heating systems are not available, along with any other systems considered for energy reduction measures during the schematic design phase. Where these systems are used, supplemental heating is required.

All loops for ground-source heat pumps must be individually isolated. Loop isolation must be inside mechanical rooms in the building the heat pump serves or in lockable vaults outside of the building. Vaults must not be located in taxiways, runways, or in aircraft parking footprints.

3.0.5 Roof-Mounted HVAC Systems

Another alternative, viable in many building applications, is the decentralized, roof-mounted, packaged HVAC system. The greatest advantage of this type of system is its lower initial cost (both mechanical system cost and building space allocation costs).

The disadvantages of the packaged rooftop equipment include the concerns of aesthetic appearance, maintenance, energy efficiency, and noise:

Rooftop HVAC equipment shall not be incorporated into the designs for the DEN terminal, its concourses, or other airside buildings without written approval from DEN Mechanical Engineer. However, this equipment does have applications for some of the support facilities. All roof-mounted equipment surfaces shall be a dull, non-reflective white or gray finish to prevent sun reflection from obstructing control tower operations. These shall be in accordance with FAA standards. Whenever a rooftop unit is utilized in the mechanical design of a building, the following concerns should be addressed in detail:

3.0.5.1 Maintenance

Equipment shall be readily accessible.

NOTE: Certain weather conditions (e.g., lightning, high wind speeds, etc.) can restrict access to roofs. Airport Operations can also restrict access to roofs at their discretion. Designers should be aware of these possible restrictions and consult the PM about risks and other options.

New roof-mounted equipment shall maintain clear space for required service areas, and new reinforced roof walkway pads shall be installed from the nearest roof access to the equipment. Walkways shall extend around the entire equipment.

3.0.5.2 Energy Efficiency

This equipment is normally air-cooled and is often not designed to be energy efficient.

3.0.5.3 Thermal Performance

Thermal performance shall comply with the requirements in the latest edition of ASHRAE/IESNA 90.1. Effects of metal-to-metal contact and thermal bridges shall be included in the calculations.

3.0.5.4 Surface Condensation

Unit cabinets shall have additional insulation and vapor seals if required to prevent condensation on the interior and exterior of the cabinet. Portions of cabinets located downstream from the cooling coil shall have a thermal break at each thermal bridge between the exterior and interior casing to prevent condensation from occurring on the interior and exterior surfaces. The thermal break shall not compromise the structural integrity of the cabinet.

3.0.5.5 Maximum Leakage

Unit cabinets shall have a maximum leakage of 0.5 percent of the total supply-air flow at a pressure rating equal to the fan shut-off pressure.

3.0.5.6 Deflection Performance

Unit cabinet wall and roof deflection shall be within 1/240 of the span at the design working pressure equal to the fan shut-off pressure. Deflection limits shall be measured at any point on the surface.

Cabinet floor deflections shall be within 1/360 of the span considering the worst-case condition caused by the following:

A. Service personnel
B. Internal components
C. Design working pressure defined for the walls and roof

3.0.5.7 Wind-Restraint Performance

All wind restraints shall be designed by Colorado Licensed Structural Engineer. Wind-restraint design shall not be delegated to the contractor.

3.0.5.8 Noise and Vibration

Proper vibration isolation is usually not provided unless special requirements are specified.

3.0.5.9 Aesthetics

This equipment can have a negative impact on the appearance of a building, depending on the elevation of other buildings or facilities in the vicinity. An architectural enclosure shall be provided around roof-mounted mechanical equipment. Any mechanical equipment or architectural enclosure that can be seen from a public area requires coordination with PM or Design Review Committee approval.

3.0.5.10 Fall Protection

Rooftops at DEN do not have built-in fall protection. Maintenance for any equipment located within 10 feet of the edge of a rooftop will require additional fall protection installed. Any forms of fall protection visible from public areas (e.g., railings) require coordination with PM for Design Review Committee approval.

3.0.5.11 Rooftop Penetrations

Any rooftop penetrations shall be detailed by Colorado licensed Structural Engineer. Penetration design by the contractor is prohibited. Penetrations shall be designed in a manner that does not void the roof warranty.

3.0.6 Variable Air Volume Systems

In a VAV system, the air volume supplied to the conditioned space is modulated to maintain the space temperature utilizing a constant supply of air temperature. This system can offer the best approach to meet two major goals, energy efficiency, and moderate initial capital costs.

The VAV system shall contain the air-handling system components described above for air handling systems, plus variable frequency fan motor drives. Fan inlet vane controls are not an acceptable method of achieving variable flow. The air distribution system shall be of a single or dual duct design based upon further analysis of such items as maintenance, capital, and operating costs. The appropriate variable volume terminal boxes shall then be provided to control the airflow to the space.

It is important with VAV systems that proper outside air ventilation rates be maintained, as well as building pressurization. Additional HVAC equipment or controls may be required with VAV systems to control pressurization. This issue will be addressed in the temperature control system requirements. The advantages of VAV systems in both flexibility and energy efficiency outweigh the additional control requirements.

VAV systems are recommended for several areas in DEN terminal buildings, office areas, concourses, and many other interior and perimeter zone applications.

Systems shall be designed to deliver a minimum 0.5" WC at the most remote VAV box.

3.0.7 Perimeter Systems

Any expanse of the exterior glass wall area in the terminal, concourses, or other areas will require a perimeter thermal conditioning system. These systems are to be designed to handle at least the conduction and infiltration loads of the perimeter walls, plus potentially some radiant solar and internal loads near the perimeter, depending on the application.

There are two suitable methods to handle the perimeter loads:

A. Perimeter finned-tube hot water radiation system

   This is effective but only serves during the winter heating system.

B. Forced air system at the perimeter

   Air circulation at the perimeter reduces pockets of stagnant hot or cold air. Air movement near the glass can also minimize the chance of condensation forming on the glass.

A perimeter forced air system is to be provided for the terminal and concourse buildings. This should be a variable volume system to provide the necessary throw-at-the-sill diffusers during mild weather. The perimeter system is preferably located at the sill rather than overhead to counteract downdraft at the windows during the winter. Some perimeter areas with low ceilings (9 ft. or less AFF) may use ceiling supply for the perimeter system; in addition, these areas could be VAV with heat if the system supplies only the perimeter and can handle both heating and cooling peak load conditions. New installations shall take into consideration the limitations to reheat imposed by ASHRAE 90.1.

Perimeter finned-tube hot water radiation systems are recommended in vestibules and other areas where there are small expanses of glass limited in height. In these cases, the winter heating condition is the only condition of need.

Caution should be used in providing sill system components so that they do not easily collect trash.

Due to the constant volume nature of parallel or series fan-powered VAV boxes and the increased maintenance costs, they are generally not allowed. If fan-powered boxes are desired, the engineer shall submit an energy, maintenance, and life cycle cost analysis over the baseline VAV system to the DEN Mechanical Engineer for justification of usage in any project.

Electric heating coils should not be considered when hydronic heating systems are present.

3.0.8 HVAC for Unfinished (Tenant) Areas

HVAC systems for unfinished future Tenant areas shall be designed to provide for heating and cooling in accordance with the same criteria as for the systems described previously. The interior spaces (defined as that space 12+/- feet from the exterior wall) shall be designed for VAV with only cooling primary air ductwork routed to the terminal units. The VAV units shall be sized to deliver approximately 1.25 CFM of supply air per square foot. Prior to setting airflows, the anticipated use of Tenant areas shall be reviewed for functions that may require airflow rates above this amount (i.e., kitchens, bars, etc.). Additional CFM shall then be built into the air handling system design to easily handle these special areas. Controls will be connected to the VAV terminal unit only if some cooling or ventilation is required in the space.

The exterior glass walls shall utilize a perimeter forced air system as described previously. The perimeter system shall be complete in the unfinished area. The interior system shall be complete only to the VAV terminal system components.

3.0.8.1 Concourse C West Expansion – Tenant Areas

Existing VAV systems serving exclusively perimeter loads shall not be demolished or modified to include interior space loads. A separate VAV or makeup air system shall address interior loads as required.

When tenant spaces are designed for future use (e.g., grey box) with no terminal equipment installed, the final contract documents shall indicate the minimum and maximum allocated airflows for each space.

3.0.9 Fan Walls

Fan wall systems are generally acceptable. When fan counts exceed more than two (2) fans in a fan wall, the engineer shall submit an energy and life cycle cost analysis over the baseline single and/or two fan system to the DEN Mechanical Engineer for justification of usage in any project. Fan failure analysis should be default for all fan walls, not just four (4) or more. The engineer shall also submit a fan failure analysis with an O&M impact study to the DEN Mechanical Engineer. Fall wall systems shall identify removal methods/paths for all major components (fan wheels, motors, dampers, etc.).

3.1 Special Systems

3.1.1 Computer Rooms

Computer rooms that do not require cooling year-round shall have their HVAC systems connected to the CUP chilled water system for cooling. Electric resistance coils shall be used for reheating when dehumidification is required. Computer room units shall also have electric, steam-generating humidifiers equipped with suitable controls that limit supply humidity. Computer rooms that require year-round cooling shall have separate dedicated air conditioning systems for winter operation. HVAC systems serving computer rooms with a design capacity greater than or equal to 65,000 Btu/h shall have an economizer per requirements of ASHRAE standard 90.1-2010.

In remote areas where chilled water and hot water are not available, computer room units shall have a dedicated, dual-circuit refrigeration system, with remote condensing units located on the building roof and with electric reheat coils. If economically feasible, a condenser water system water-cooling tower may be installed to replace the condensing units. The condenser must have head pressure control and a P trap if the lineset has more than a 10-foot drop. A hot gas bypass shall also be installed.

3.1.2 Evaporative Cooling

Since evaporative cooling is economically practical, it should be considered where acceptable air quality is available. The use of evaporative cooling is limited at DEN to specific areas such as support facilities. Evaporative cooling shall not be considered as the sole means of cooling for the public areas in the terminal or concourses.

Evaporative cooling may be considered as an energy reduction measure to be utilized in conjunction with the DEN Chilled Water System. When evaporative cooling is used, the engineer shall submit an energy and life cycle cost analysis over baseline DEN Chilled Water System cooling without an additional evaporative cooling unit to the DEN Mechanical Engineer.

Total evaporative cooling may be utilized, with an indirect/direct method of operation to limit the humidity level. The use of evaporative cooling is economically attractive, especially in the low-humidity climate of the Denver area. However, if a backup chilled water or DX system is incorporated with the evaporative cooling to handle humid days, the economics are unfavorable, and this should be avoided.

The disadvantages of the indirect/direct evaporative cooling units that must be addressed in the design process include the following:

A. Additional AHU cost and space requirements.
B. Increased maintenance requirements. (Evaporative media replacements, chemical treatment, water usage, etc.)
C. Increased potential for water leakage and resulting damage.
D. Decreased reliability due to the historical rapid deterioration of equipment utilized in evaporative cooling.

3.1.3 Humidification

Areas having special humidification requirements, such as computer rooms, radar equipment rooms, radio equipment rooms, etc., shall utilize individual electric humidifier units located either in the zone ductwork or in the individual room air conditioning units. Humidification through the main air handling systems is not to be provided. Humidifiers shall be the steam generator type. Provide high-limit humidity sensors downstream of the humidifiers. Downstream ductwork shall not be internally lined.

3.1.4 Air Curtains

Air curtains, plastic curtains, and rapid operation doors are to be considered for use at doors and openings at all maintenance-type facilities and at baggage doors and openings.

Overhead fan-coil units or fan-powered terminal boxes may be used as a modified type of air curtain at each concourse gate aircraft entrance. The fan-coil units shall be activated, if not already in operation, whenever the gate aircraft door is opened utilizing a 30-second time delay, and the supply air temperature is to be controlled from a space thermostat.

Air curtain-type units shall be used at all terminal entrance vestibules. These air curtain units are controlled by vestibule thermostats. Air curtains shall be electric or hydronic.

3.2 Ventilation Systems

3.2.1 Outdoor Air Requirements

Outside air shall be brought in through the air handling systems to satisfy minimum ventilation requirements plus provide building pressurization and minimize air infiltration at building entrance door areas.

Existing outdoor air requirements on air handling equipment in the terminal complex Facilities were designed around ASHRAE standard 62-1989. Outside air ventilation amounts shall be provided in accordance with the latest edition of ASHRAE standard 62 or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. The Engineer shall coordinate those requirements with the DDS and provide electronic copies of correspondence and documentation of the final design direction to the DEN PM. The Engineer is responsible for providing documentation that states the existing equipment can comply with any modifications in outdoor air.

Outside air intakes shall be located high and away from landside vehicle traffic and airside jet exhaust to the greatest extent possible, a minimum of ten feet above grade. All ventilation air will be brought in through air intakes in the mechanical penthouses. If additional ventilation air is required, consideration should be given to using indirect-fired gas make-up air units or heat pump make-up air units with electric reheat with roof-mounted intakes. If heat pump make up air units with reheat are selected, refer to 3.0.4 Heat-Pump Systems for heat pump requirements. In some locations, National Fire Protection Agency (NFPA) 415 may have requirements that are more prohibitive and shall be followed.

3.2.2 Air Economizer Control

All air-handling units used for comfort cooling with a design capacity greater than or equal to 54,000 Btu/hr shall be equipped with airside, dry-bulb economizer cycle operation. The control system for this operation must be arranged to modulate outside and return air dampers to maintain a mixed air setpoint temperature. Outside air dampers will close to the minimum position and return air dampers open when the O.A. is 75°F (adjustable).

It may not be appropriate to provide AHUs to be located on the apron level and similar areas with 100% outdoor air capability due to the air quality in these areas. Therefore, some air handlers shall be provided with continuous minimum outside air levels. All units with minimum outdoor air requirements shall have freeze protection. Upon restarting supply fans after freeze protection has tripped, outdoor air dampers shall remain closed for 5 minutes (adjustable) to allow supply air temperature sensors or freeze stats to reheat to avoid re-tripping freeze protection.

These units shall utilize waterside economizer cycles (if applicable).

3.2.3 Return Air/Transfer Air

Return air from the conditioned space back to the AHU should be via ductwork and ceiling plenums. The pressure drop in the return air system shall be minimized in the design. Return air fans should not be required in most cases. Maximum velocity shall be 500 fpm over net free area for general return and transfer air openings and 200 fpm over net free area for smoke control openings.

Eggcrate grilles shall be used in return air plenums that are used for smoke control. Perforated face grilles shall not be used.

3.2.4 Ventilation Rates

As described earlier in this document, the outside air ventilation rate shall be as recommended in the latest edition of ASHRAE standard 62.1. Careful consideration shall be given to these new recommended rates, particularly considering recent attention in the HVAC industry to indoor air quality. Applicable ventilation rates are published in ASHRAE standard 62.1.

Outside air requirements, unless otherwise specified, shall be as follows for normal occupancy levels.

The occupancy load in many public areas of the airport (i.e., concourses, hold rooms, ticketing areas, baggage claim, etc.) is highly variable. As an alternate to the ventilation air flows indicated as based on normal occupancy levels, it is acceptable to calculate the minimum ventilation rate of 10 CFM per person, based on peak load occupancy, unless exhaust requirements override this amount.

Ventilation shall be provided in all ground-level spaces that may have occasional or full-time occupancy. This ventilation shall be such as to minimize any possibility of an accumulation of radon gas; however, shall not be less than one (1) air change per hour.

Unoccupied crawl spaces in contact with the ground shall be ventilated likewise to eliminate radon gas hazards at a rate of one (1) air change per hour- on a time clock to run not less than four one-hour periods in each 24-hour day.

3.2.5 Filtration

Air filtration is an important consideration in the design of HVAC systems to serve airport facilities. Air should be brought in at the roof or penthouse level wherever possible to use the highest quality air available. As a minimum, outside air is to be filtered using a 30" x 30" x 2" dry type pre-filter section having a minimum rating of MERV 8, 30" x 30" x 12" dry type filter section having a minimum rating of MERV 13 and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

Filters for small air-handling units serving maintenance or non-public areas should be provided with a 4" dry type pre-filter section having a minimum rating of MERV 10.

All filter sections shall have a digital differential pressure transmitter that connects to the EMCS for trending and maintenance activities.

3.3 Heating, Ventilation, and Exhaust Systems

3.3.1 General

This section covers areas of the building that are primarily mechanically heated and/or ventilated only, no air conditioning to be included. In general, ventilation rates, filtration, etc., mentioned previously for HVAC systems will apply unless otherwise indicated. Special exhaust requirements are also discussed.

3.3.2 Bag Makeup and Tug Drive Area

3.3.2.1 Ventilation

These spaces shall be maintained under negative pressure in relation to the main terminal (public space) area. This will be accomplished with the use of exhaust fans. The exhaust shall exceed the 100% O.A. makeup air quantities by approximately 10% in the bag makeup area. Ventilation rates shall be a minimum of 6 air changes per hour in the bag makeup area and 10 air changes per hour in the tug drive area if internal combustion engines are utilized. If all electric vehicles are utilized, the air change rate may drop to 2.0 air changes per hour of makeup air. Makeup air units shall be sized to supply 60°F discharge air during winter design conditions unless heat recovery is being used.

3.3.2.2 Heating

The bag makeup area shall have a 100% outside air makeup unit with filters and heating coils or indirect gas-fired equipment. In addition, hot water unit heaters or low-intensity infrared heaters shall be strategically located throughout the area and near overhead doors to maintain space temperature. Consideration will be given to providing low-intensity infrared heat in lieu of some unit heaters, depending on overhead door activity. This will be based on input from the individual Tenants that will utilize this space. Consideration shall also be given to recover heat from the exhaust air stream. The tug drive shall be tempered with low-intensity infrared heaters placed at bag drop-off areas.

3.3.3 Truck Dock Ventilation

An exhaust system shall be provided to ventilate truck docks on the apron level. This exhaust system shall continuously provide 10 air changes per hour in the truck dock area. This ventilation system will provide the added benefit of creating air movement and reducing carbon monoxide build-up.

3.3.4 Toilet Exhaust

Unless a more stringent requirement occurs in the current building code or current ASHRAE standards, the ventilation (exhaust) rate for all toilet room facilities shall be a minimum of 0.5 CFM/sq. ft. of floor space, six air changes per hour, or as required by the latest edition of ASHRAE 62.1, whichever is more stringent. Toilets with extremely high traffic, such as those located in concourse areas, should have a minimum exhaust rate of 10 ACH. Variable flow systems shall not be considered for public spaces.

Under no circumstance shall a positively pressurized toilet exhaust duct run through a return air plenum or occupied space.

3.3.5 Service Level

3.3.5.1 Ventilation

Provide motorized-dampered air intakes and exhaust fans in all electrical and mechanical equipment rooms for adequate ventilation. Air intakes should be from the ramp or apron area. Compliance with applicable fire codes is essential.

3.3.5.2 Heating

Provide hot water or gas-fired unit heaters to heat the storage and equipment room areas where a heat loss is involved.

3.3.6 Atrium/Great Hall

The Atrium or Great Hall of the terminal building shall contain a relief air system in the high bay area that will relieve air due to pressure or temperature build-up. A makeup air unit shall also serve the high bay area to provide ventilation air and pressurization when required. These systems shall also be incorporated into a smoke removal system as required by NFPA and the Denver Building Code for high-rise structures.

3.4 Existing Systems

3.4.1 General

The following is a general overview of the HVAC systems used in the base buildings at DEN. This narrative is general in nature and should not be used as the basis for sizing of equipment in tenant spaces, general specifications, and/or control sequence modifications.

3.4.2 Existing Air Handling Systems

In the present designated Tenant areas of the Terminal building, Concourses, and AOB, the HVAC systems consist of variable air volume air handling units with heating and cooling capability. The VAV systems provide the flexibility required to maintain comfort during shifting cooling loads. The holdrooms in the Concourses are supplied by both VAV and constant-volume air handling units. The exterior walls are supplied by heating-cooling VAV boxes that discharge out perimeter slot diffusers. The interior areas are supplied by constant-speed fans.

The air handling units in the Concourses and Terminal are located on the fourth level. The air handling units supplying the AOB are located on the roof. In the North Terminal, the air handling units are in the third-level mechanical equipment rooms. The first and second levels of the terminal have hot water only. The third-level has a constant volume of air and access to both hot and chilled water. Verify the locations and available quantities for Tenant usage with the PM.

The Concourse basement levels have a limited amount of Central Plant heating water available for Tenant development. Most heating will have to be provided by electrical heat or gas-fired equipment. Presently the basements have four (4) air changes per hour of tempered air. In the Concourse B basement, the Ventilation/Smoke Control Fans (VSCFs) serve both ventilation and smoke exhaust. VSCFs are a legacy system and are being phased out. No new VSCFs shall be installed; new ventilation systems shall not serve double duty as smoke exhaust systems. For smoke control requirements, refer to the Smoke Control chapter in the Life Safety DSM. This smoke and ventilation air is not available to the Tenant for comfort heating or cooling.

The air handling units are dedicated to distinct zones with overlapping airflows via a common return/relief fan system. The perimeter zones are VAV and fan-powered units with heating water heating at the terminal unit. The interior concourse holdrooms and subcore areas are cooling only VAV units. The central circulation zone is served by a constant volume system. The VAV perimeter air handling unit discharge temperature will be reset based on the “worst space load.” All VAV heat terminals have double-ended control to increase air temperature and volume in unison.

The air handling units were sized based on normal heating and cooling loads for the public levels. The airflows are governed by the sensible cooling and winter heating load. There is no provision for latent loads. Air supply was based on the following:

Table 3-1: Basis for Existing Air Handling System Air Supply

Space	Minimum Occupancy
Bars	7 SF per person
Concession Areas	30 SF per person
Dining Rooms	15 SF per person
Holdrooms	100 SF per person
Offices	100 SF per person

Due to the large glassed area curtain wall configuration of the south perimeter zones of the Concourse and Terminal, large airflows were required by the South perimeter zone. To minimize the size of the South perimeter air handling units, a portion of the load was shared by the VAV air handling units serving interior zones.

Air handling unit airside economizer controls utilize free cooling when possible during mild weather. Outside and return air dampers modulate to maintain 55º± mixed air temperature. At the minimum mixed air temperature of 45ºF± or on a temperature rise over 75ºF±, the outside air damper goes to a minimum position. Space temperature modulates hot and chilled water coil valves.

Variable volume control is monitored from static pressure control sensors located approximately 2/3 of the total duct length downstream of the air unit supply fan.

The control logic permits a reduction in outside air ventilation requirements when unoccupied. The specified ventilation rate is the minimum condition required at peak occupancy. Control elements for air handling unit operation also include high discharge fan static, low-pressure return air fan static, smoke detectors, and multiple function freeze stats.

Return air fan tracks the supply air fan to return 80-90% (adjustable) of the total related air handling units total supply to ensure positive space pressure.

3.4.3 Existing HVAC Air Distribution

The existing perimeter supply air system in the Terminal, AOB, and Concourses consists of in-place heating-cooling VAV terminal air units complete with supply ducts and slot diffusers. The amount of perimeter air per linear foot of the outside wall varies with the location. The interior supply air system generally consists of a SMACNA Class 4" WG primary duct that is supplied from the existing building supply system. The duct is routed in the ceiling of the Tenant spaces.

3.4.4 Existing Base Building Compressed Air Systems

Compressed air is generated from a centralized compressed air facility with oil-free reciprocating or screw-type compressors. Because of the critical nature of this system, there is one operational system with at least one stand-by system under all circumstances. This means that if one system is down for maintenance, there will be one system in operation and one additional system as a stand-by for a minimum of three systems.

The main distribution system air pressure is 80 to 100 psig with pressure-reducing stations to reduce the pressure to the respective usable levels for temperature control systems. The main control air is dried with externally heated, regenerative air dryers to a-40ºF dewpoint to prevent airlines from freezing ambient air temperatures. The dryers have adequate filters located both before and after the dryer. The dryers are interlocked to operate with their respective air compressor.

These systems are largely undocumented. Any project modifying systems with pneumatic controls shall not reuse the pneumatics. All new work shall be DDC.

3.4.5 Existing Ventilation/Smoke Control Fans (Historical Reverence Only)

Ventilation/Smoke Control Fans (VSCFs) are a legacy system used exclusively in the basement of Concourse B. The VSCFs at DEN are being phased, and new VSCFs shall not be installed. VSCFs work by using dampers to reverse the flow of air through ventilation ductwork, changing their function from providing ventilation to smoke exhaust.

No new VSCFs shall be installed at DEN. All fans used for smoke exhaust or smoke pressurization shall be used exclusively in these functions and shall be labeled as Smoke Exhaust Fans (SEFs) or Smoke Pressurization Fans (SPFs), respectively. Refer to the Smoke Control chapter in the Life Safety DSM for smoke control requirements.

3.5 Tenant Remodel Requirements

3.5.1 Tenant Design Parameters

The Tenant shall provide adequate cooling to provide comfort conditions. Tenant shall not exceed the maximum amount of Lighting and Connected loads as defined in the Electrical DSM. If the allowable electrical load exceeds the following cooling capabilities, the Tenant shall provide additional cooling. The Tenant shall provide heat load calculations to confirm adequate cooling is being provided.

The Tenant shall provide a complete HVAC system to meet loads that exceed the requirements listed below. The Tenant shall verify the heating and cooling loads from the perimeter, adjoining structures, and adjacent spaces affecting the Tenant area. All Tenant areas in the Terminal are in the interior spaces and are unaffected by the perimeter heating /cooling loads. Tenant Designers shall provide DEN with heating and cooling load calculations.

Reference the Tenant DSM for Tenant Remodel Requirements.

3.5.2 Existing Base Building Mechanical Design Capabilities

The base building air handling system in the Concourses has been designed to accommodate the following loads for Restaurants, Food Courts, Offices, and Concession Spaces (aka ALLOWABLE LOAD):

A. Basic Office, Retail, Airline Tenant: Exterior Load + 1.00 CFM/SF
B. Restaurant Tenant: Exterior + 1.25 CFM/SF for the seating area. Kitchen is to be conditioned with a tenant-supplied mechanical make-up air system.
C. Bar Tenant: Exterior load + 1.25 CFM/SF
D. Food Court Tenant: Exterior load + 1.25 CFM/SF for seating areas. Source of make-up air will be by each tenant and coordinated between DEN and each tenant.
E. Concourse C West expansion & Concourse B South Regional Jet Facility: No Tenant HVAC (hydronic on airside) accommodations have been made. Tenant shall provide a complete stand-alone HVAC system.
F. Concourse A West Expansion (MOD 6W and 9W). See Matrix A: DEN Concourse A West Expansion Concessions.
G. Concourse B West Expansion (MOD 8W and 9w). See Matrix B: DEN CEP Concourse B West Expansion Concessions.
H. Concourse C East Expansion (MOD 6E and 9E). See Matrix C: DEN Concourse C East Expansion Concessions.

3.5.2.1 Hotel Level 5 - Fan Coil Units are Sized Only for Existing Shell Load

The Tenant shall provide adequate cooling for occupant comfort conditions with the Base Building supply air. When the Tenant's defined load cooling load exceeds the allowable load listed above, the Tenant shall provide a separate HVAC system to meet the load difference. If the allowable electrical load exceeds the allowable load, the Tenant shall provide additional cooling equipment. This may be accomplished with air conditioning units utilizing the DEN chilled water system or with a make-up air unit with DX cooling and an air-cooled condenser. Heating may be supplied by the DEN heating water system, direct or indirect-fired natural gas heat, or electric heat. The designer shall verify the availability of the existing system capacity. No system shall be assumed to have sufficient capacity without supporting calculations.

3.5.3 VAV Terminal Air Units

The interior Tenant VAV boxes and controls shall be furnished and installed by the Tenant. All variable air volume (VAV) units shall be pressure independent with normally closed, electronic damper actuators that have a minimum air flow rate adjustment to zero (fully closed). Heating coils shall be sized for heating the maximum air flow rate of each unit. All heating coil control valves shall fail open. All VAV terminal boxes shall have native BACnet communication and connect directly to the DEN EMCS. Refer to Chapter 5- Controls for additional requirements.

Perimeter VAV boxes are the property of the DEN and shall not be altered from original design. These systems are designed specifically for the curtain wall load. Tenants shall not use perimeter VAV systems for supplemental conditioning due to new Tenant loads. In some cases, VAV boxes, controls, and diffusers will need to be moved to meet Tenant architectural cases. Relocated equipment shall perform in the exact manner of the original installation. Refer to other chapters for operation and accessibility requirements of DEN systems.

Designer shall ensure all components of DEN VAV terminals are completely accessible for maintenance and no additional HVAC or Tenant equipment is required to be removed from operation to complete maintenance activities. Control modules shall have a minimum twenty-four (24 x 24) inches of clear space in front of the controls and an area directly to floor below to allow for maintenance activities.

3.5.4 New Tenant HVAC Systems

Most Curtain Walls areas on the Concourses and the Terminals are served by existing base building heating-cooling VAV and/or Fan-powered terminal air conditioning units. The exterior space is defined as that space from the exterior wall to 8 feet in from the exterior wall.

The Tenant shall provide terminal air units and appropriate ductwork if required for the perimeter areas. The system shall consist of heating-cooling VAV boxes.

The use of light-troffer diffusers is not allowed.

Interior spaces are designed for VAV terminal air units with 55ºF± cooling-only air available from the existing primary duct supplied from the existing system. The Tenant shall connect to the primary duct to supply perimeter or interior areas and route to the VAV terminal units.

3.5.5 New Tenant Air Handling Units

Areas requiring year-round cooling requirements (such as computer rooms) shall have individual refrigerant systems. They shall be complete with roof-mounted or horizontal cabinet-mounted condensing units if access to the outside air for cooling through an economizer control is not available. Apron-level stand-mounted condensing units should be avoided due to the increased potential of damage by apron service equipment.

Areas having special humidification requirements, such as computer rooms, radar equipment rooms, and radio equipment rooms, shall utilize electric humidifier units located in the zone ductwork or in unitary or split air conditioning units. Humidification from the main air handling system is not provided.

Evaporative-type air handling units will be considered for isolated buildings such as maintenance, shops, and hanger building offices. In these instances, only indirect evaporative cooling with backup refrigeration will be considered. Direct evaporative cooled systems will be allowed for kitchen systems if all other refrigeration cooling systems are deemed not practical in writing by the DEN Mechanical Engineer.

All roof-mounted equipment surfaces shall be a dull, non-reflective white or gray finish to prevent sun reflection from obstructing control tower operations. These shall be in accordance with FAA standards. New roof-mounted equipment shall maintain clear space for required service areas, and new reinforced roof walkway pads shall be installed from the nearest roof access to the equipment. Walkways shall extend around the entire equipment.

3.5.6 Food and Beverage Tenant Equipment

All kitchens shall be air-conditioned. The exhaust requirements will be determined by the cooking exhaust hoods installed within the facility. All cooking and food reheating equipment, including ovens, fryers, grilles, conveyor toasters, and similar, shall have dedicated exhaust hoods serving the equipment. The kitchen exhaust system shall be designed in accordance with the latest version of NFPA 96, “Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations,” and the latest editions of the International Mechanical and International Energy Conservation Codes, including City amendments. Re-circulating hoods are not allowed.

Tenant shall furnish and install, if applicable, a complete kitchen exhaust system and mechanical make-up air system. In the Concourses and Terminal, each Food Court Tenant shall provide their own mechanical make-up air system. Kitchen grease exhaust hoods shall be UL listed. UV systems may be used in type 1 hoods with the exceptions of heavy-duty and extra heavy-duty cooking appliances. In heavy-duty and extra-heavy-duty applications, UV hoods may be used in combination with another approved grease, smoke, and odor control system.

Exhaust and make-up air quantities shall be determined per food service Tenant. The system shall be complete with a hood, grease removal system, exhaust fan, and control panel. Roof-mounted exhaust fans shall be utility-set type and arranged in an upblast configuration.

Wherever food service has the potential for odor propagation outside of tenant areas, the tenant shall provide exhaust and make-up air.

The exhaust air from kitchen hoods shall be free from grease, vapor, and smoke. Installation of a water wash scrubber with filters shall be the preferred method. In the Terminal Building, the air scrubber shall be mounted on the roof. In the Concourses, the Tenant shall provide space for the exhaust fan and air scrubber within the Tenant's return air plenum space. Tenant air scrubbers may only be mounted on Concourse roofs with written permission obtained from DEN Mechanical Engineer. All roof-mounted tenant equipment in the Terminal and Concourses must conform with standards in 3.0.5 Roof-Mounted HVAC Systems. All clean-outs for grease-laden exhaust ducts must be located in Tenant space. Where permitted by code, and only with written permission from DEN Mechanical Engineer, Tenant kitchens may forgo scrubbers in grease exhaust. Where forgoing scrubbers, grease exhaust ductwork must terminate on the building roof. Tenants must provide CCTV showing the grease exhaust termination and provide DEN with all CCTV feeds. The Tenant must conform with DEN data retention and security standards when providing CCTV to DEN. DEN retains the right to order the Tenant to install a scrubber at no cost to DEN at a future date should odors and/or smoke from grease exhaust be detectable inside the building or if grease buildup causes damage to DEN property.

Designer to include a note on the drawing that upon completion of construction, general contractor is to provide an inspection report to DEN from a qualified kitchen exhaust cleaning contractor, confirming that sufficient access to clean the entire kitchen grease exhaust system has been provided. Any required modifications to allow complete system cleaning shall be installed prior to DEN acceptance.

Heat recovery from kitchen hood exhaust should be considered in the final design if grease buildup or collection can be avoided. Make-up air should be heated to 70ºF or cooled via evaporative cooling equipment and supplied at the kitchen hoods. Packaged, factory-designed, and NFPA-approved kitchen exhaust hoods with make-up air systems are acceptable. To reduce cross-contamination and odors, no air from active cooking commercial kitchens shall return to the DEN base building air handling systems. Under no circumstance shall a positively pressurized kitchen or hood exhaust duct run through a return air plenum or occupied space.

Makeup air for kitchens shall be provided by a dedicated makeup air unit designed for a minimum of 100% of exhaust airflow. In no instance shall makeup air be taken from HVAC systems adjacent to the kitchen. All kitchens shall maintain a negative air balance in respect to adjacent spaces during active cooking operations.

See Chapter 5- Controls for additional tenant controls requirements.

3.5.7 Electrical Closets/Communications Rooms/Fire Control Rooms/Fire Pump Rooms

Ductwork shall not be routed through transformer vaults and their electrical equipment spaces and enclosures except for ducts specifically serving those areas. If a Tenant's leased area is on a level directly above an electrical closet and if that tenant requires water, sanitary waste, or grease waste lines, those lines shall be installed in such a manner to avoid being routed directly above the electrical closets. Sanitary waste and grease waste lines may not be routed in or through Fire Pump Rooms. Lines above the Communications and Fire Control Rooms shall be sleeved to protect equipment with written approval from DEN Mechanical Engineer.

3.6 Sustainability

As part of the City and County of Denver's Office of Climate Action, Sustainability, and Resiliency (CASR), the ***Energize Denver Ordinance***, which establishes energy use intensity targets for buildings over 25,000 sq. ft., DEN is working to reduce our carbon emissions impact. As such, gas-fired HVAC equipment or fixtures, except for kitchen cooking equipment (stoves, ovens, etc.), needs to be evaluated by the consultant for alternate energy sources.

Evaluation needs to include available electrical and heating water capacities as a replacement for natural gas. Equipment heating source evaluations shall be presented and accepted in writing by the DEN Mechanical Engineer prior to proceeding with the design.

End of Chapter

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Chapter 4 - Air Distribution Systems

4.0 Air Distribution Systems

4.0.1 Ductwork Design

Ductwork layout and sizing shall be performed using the best practices to ensure minimum energy loss by thermal transfer and friction. Design shall ensure that the minimal duct length is achieved and that no unnecessary loops or branches are used. Ductwork shall be routed in the most direct route feasible. Ductwork fittings shall be selected based on best practices for optimal performance in energy (friction and thermal) and sound transmission. Ductwork shall generally be designed for low pressure, i.e., 2.0" WG or less, positive or negative. All medium-pressure ductwork (operating pressures in excess of 2" WG, positive or negative) shall be sized based on the static regain method. All low-pressure ductwork shall be sized using either the static regain method or the equal friction method. The existing main ductwork upstream of VAV boxes is considered medium pressure. All ductwork systems shall be designed to minimize noise transmission through the ductwork and avoid noise generation from components or fittings. Ductwork air velocities shall not exceed the following limits:

Table 4-1: Ductwork Air Velocity Limits

Area	Velocity Limit
Mains - Equipment rooms and non-occupied spaces	3400 fpm
Mains - Occupied spaces	2200 fpm
Branch or mains with diffuser connection	600 fpm
Branch with diffusers	1200 fpm

Aspect ratios shall not exceed 4:1 for mains

4.0.2 Ductwork Requirements

Ductwork shall be either rectangular or round (spiral) as appropriate for the specific application. All designs shall be in accordance with SMACNA HVAC Duct Construction Standards and the technical criteria in this manual. All supply air distribution ductwork shall be galvanized sheet metal with flanges, seams, supports, etc., to match the appropriate duct classification as defined by SMACNA unless moisture in the system dictates the use of aluminum or stainless-steel materials. Kitchen exhaust ductwork shall be welded stainless steel.

Although SMACNA allows spin-in fitting for medium-pressure ductwork, because they are difficult to differentiate in field inspections from low-pressure fittings, spin-in fittings are not allowed at DEN. Spin-in fittings shall not be represented on plans or sketches for medium-pressure systems. Spin-in fittings are allowed on low-pressure systems.

Exposed ductwork used as an architectural feature shall be round and constructed of sufficient gauge metal to prevent dings or dents. Ductwork material shall be either aluminum finish or suitable for painting. No external insulation shall be provided on architecturally exposed ductwork. Lined ductwork shall be used in exposed areas when radiated sound level exceeds that required in Chapter 1- General.

All 90-degree elbows in both medium and low-pressure ductwork shall contain double-walled, airfoil-type turning vanes unless long-radius elbows are used.

Ductwork near air-handling units and outside air ductwork will be lined, as required, for thermal performance, noise control, and condensation control.

The Design Consultant shall designate the calculated duct static pressure on the drawings to establish duct construction classification. Changes in duct pressure classifications shall be called out via note or symbol.

Flexible round duct shall be a maximum of 5 feet in length and be of material acceptable by the Denver Building Code.

In general, no ductwork shall be run underground.

No ductwork shall be routed through/across the AGTS tunnel.

4.0.3 Dampers

All control dampers shall be the parallel-blade type.

A. Outside air intake, dampers shall have air-tight seals at both the edges and ends of the blades. The seals shall be of a material that will not disintegrate with exposure to jet exhaust fumes.
B. Control dampers shall be provided on all main branch take-offs and on the main ductwork downstream of a branch take-off.
C. Fire and combination fire/smoke dampers shall be UL listed and conform to the standards and requirements of the International Building Code and CCD building code amendments. To limit fire alarm addressing and maintenance of combination fire/smoke dampers, these dampers are only to be installed where required by code; use fire dampers to the greatest extent possible. Fire and combination fire/smoke dampers shall have access doors provided for service and maintenance no more than 12" away from the damper. Access doors shall be 12" x 12" or larger.

Due to long intervals of typical operational modes and various system pressure changes, all backdraft dampers shall have motorized actuators. No barometric-type dampers shall be specified on any system without written permission from DEN mechanical engineer. Tenant projects shall not use barometric-type dampers. Motorized dampers shall fail in a condition that provides maximum protection to occupants and equipment.

4.0.4 Diffusers

Various types of diffusers are to be considered based on architectural input. Consideration shall be given to quality, durability, capacity, aesthetics, throw, and noise level. Coordinate with the architect all diffuser types and locations. Linear slot diffusers shall be individual, 4-foot maximum sections with individual supply boots. Perforated face diffusers are not to be used. Diffusers with face-adjustable dampers/throw blades shall not be used.

4.0.5 Grilles

Standard core 1/2" x 1/2" x 1/2" eggcrate grilles shall be used in return, air plenums/systems. Eggcrate grilles shall have a minimum free area of 90%. Perforated face, louvered face, or other face types shall not be used in return air systems in smoke control areas.

4.0.6 Transfer Air

Transfer air openings are required in all walls to structure, in return, air plenums and smoke control zones. Transfer air openings shall be sized for a maximum velocity of 200 fpm in smoke zones and 500 fpm in return air plenums that are not used for smoke control. Sizing shall accommodate the entire return air/smoke control system to the point of installation. Refer to the Life Safety DSM for additional requirements.

4.0.7 VAV Terminal Air Units

Designer shall ensure all components of VAV terminals are completely accessible for maintenance, and no additional HVAC or Tenant equipment is required to be moved or removed from operation in order to complete maintenance activities. Control modules shall have a minimum of twenty-four (24) inches of clear space to allow for maintenance activities. Clear space shall be defined to mean the space directly in front of the device. Access to the clear space shall also be unobstructed. VAV controls shall be of the direct digital control (DDC) type and shall be able to interface with the Johnson Controls MetaSys control front end.

4.0.8 Security Grates

Security grates shall be installed on all ductwork and transfer air openings larger than 144 square inches between public spaces and private/security spaces. All roof penetrations larger than 144 square inches with a direct path of access indoors shall be required to have a security grate.

4.0.9 Ductwork Supports

Cable or wire ductwork supports shall not be used.

4.0.10 Presentation of Ductwork Systems

All ductwork shall be shown on construction documents as double lines, regardless of the drawing scale and pressure classification. Round ductwork shall be indicated with a centerline. Limits of all lined ductwork shall be identified clearly by double-line symbology. The Design Consultant shall detail all ductwork fittings and connection types.

Single line ductwork can be shown on Schematic Design, Design Development, 30%, and limited portions, 60% submittals only.

All ductwork shall be identified by system type (exhaust, supply, return, etc.). All callouts for ductwork continuations off the plan shall identify its termination/origin. All callouts shall be in the direction of airflow. General notes of direction are not allowed.

Table 4-2: Allowable Direction Callouts

Not Allowed	Allowed
24 x 24 up	24 x 24 SA up to mezzanine tenant service
24 x 84 SA from below	24 x 84 SA from AHU-D
22 x 36	22 x 36 EX
84 x 36 up	84 x 36 RA to REF-4

Designers shall indicate on plans all changes in SMACNA duct static pressure classifications. Changes shall be represented with a double diamond symbol containing the static pressure of each section. For example:

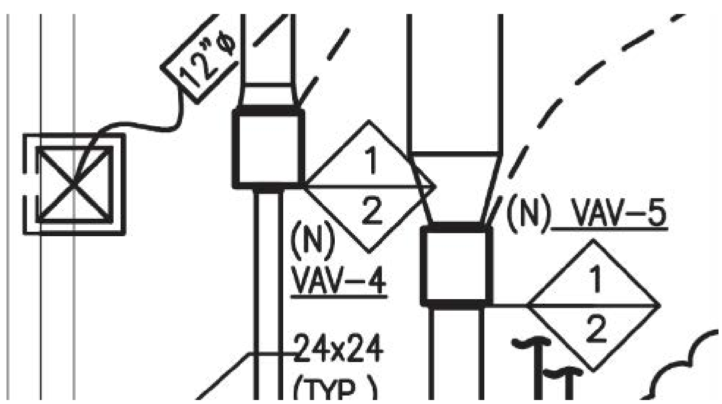

Figure 4-1: Allowable Duct Static Pressure Callouts Examples

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Chapter 5 - Controls

5.0 Controls

5.0.1 General

A complete system of automatic controls shall be provided to maintain space conditions within allowable limits. When heating and cooling are incorporated into one system for personnel comfort, the automatic temperature controls shall not be capable of simultaneous heating and cooling and shall provide a deadband. Automatic temperature control devices for personnel comfort shall have a heating control range between 65°F and 74°F and a cooling control range between 72°F and 85°F.

Not all controls are for HVAC systems. Designer to coordinate with DEN for requirements for plumbing and other systems. Plumbing systems will include electric water heaters not used in Tenant spaces, sump pump status and alarms, emergency drainage flow switches and domestic booster pumps. Water detector alarms at water entry and mechanical rooms are to be included near backflow preventors and around each air-handling unit. Water detector alarms are to close the source of water that may be leaking at the room's boundary.

The system shall consist of all necessary control devices, control valves, control dampers, damper motors, pneumatic and electric switches, relays, gages, panel boards, tubing, and fittings, including all necessary accessories required for a complete and operative control system. All control wiring and control system electric power is to be furnished to provide complete environmental control and central panel functions. Products are to be of the latest design to avoid becoming untimely obsolete.

Control systems shall be electronic, digital systems controlling all HVAC equipment utilizing local microprocessor field panels located in the applicable adjacent equipment rooms. The field panels shall be capable of interfacing with the Energy Management Control System (EMCS) and shall be equipped with backup power in accordance with the Electrical DSM, Chapter 2. Electric motor operators shall be used for all new valve and damper actuators; pneumatic operators are used for many existing valve and damper actuators. The existing pneumatic control systems located throughout the concourses and terminal are largely undocumented and should not be used for new projects.

Equipment utilizing manufacturer's controls system shall control all elements of their equipment and not rely on external controls for part of its operation. As an example, equipment such as a DOAS unit with heat recovery to control freeze protection and not rely on an additional controls system for that function. Intent is to not have three different controls system for a single system.

The local field panels shall be tied to the Facilities EMCS for equipment outside of the CUP or the CUP EMCS (for CUP equipment) located at the CUP but capable of standalone operation.

Projects integrating DDC controls, or other non-HVAC related controls systems, shall be completely independent of the HVAC controls' MS/TP networks and controllers. The intent is that non-HVAC controls cannot affect the HVAC systems during a loss of continuity in the controlling system's network.

Tenants that utilize their own HVAC systems and subsequently the maintenance of those systems, must have controls that indicate alarms and equipment shutdowns. Tenant controls systems are not to be integrated into the DEN EMCS. Where there are DEN building systems used by the tenant, additional critical alarms must be sent to the EMCS for response by DEN. Such critical alarms would include low air temperature alarms at make-up air units utilizing base building heating or chilled water systems, low heating water return temperature, etc. The intent is to give an indication of a failure of tenant equipment such that DEN Maintenance will be notified that a DEN maintained system may be in danger of being compromised.

Designer is responsible for locating sensors where external influences will not affect the sensor (i.e., don't locate space temperature sensors where sunlight can hit them or near heat producing equipment).

Reference the Communication and Electronic Systems DSM for more information and requirements.

5.0.2 Existing Base Building HVAC Control Systems

The HVAC host control system consists of a network of fully independent direct digital control (DDC) controllers that are interconnected via a multiplexed digital data trunk. Data available to any one direct digital controller is available to all DDC controllers. Each macro controller may supervise a sub-network of micro-level DDC controllers. Sensor input devices and output devices shall be connected to either the macro or the micro-level DDC controllers. Each room with macro controllers has a local operator interface using an English language format. The control system interfaces over a phone modem or Ethernet connection with a main server in the Network Operations Center and can be accessed remotely. Each macro in the system is connected together by a Local Area Network (LAN) for peer-to-peer communication, multiple-user programming, and data gathering.

Existing building control system manufacturers and integration requirements shall be verified with the DEN Mechanical Engineer during project design. The following listing is subject to change as ongoing projects are implemented:

A. AOB: Honeywell. Transitioning to Johnson Controls.
B. Terminal: Honeywell and Johnson Controls. Transitions to Johnson Controls.
C. Concourse A: Honeywell and Automated Logic. Transitioning to Johnson Controls and Automated Logic.
D. Concourse B: Johnson Controls BACnet
E. Concourse C: Honeywell. Transitioning to Johnson Controls, except for Concourse Expansion Program C-East (Building Modules 5E-10E), which will remain Honeywell.
F. CUP: Johnson Controls
G. Hotel/Transit Center (HTC): Johnson Controls LonWorks with JCI Metasys and Honeywell EBI Interface
H. PCA Plants: Johnson Controls with JCI Metasys interface
I. Gate PCA Systems: Various interfaces. New systems shall be compatible with JCI Metasys. Ground-mounted units must be hard-wired. Bridge-mounted units may utilize wireless communication.

As of 2016, all new controls shall use the BACnet communication protocol to connect to the existing Johnson Controls Inc. Metasys Control System (EMCS). In many locations, routers exist for connections for new controls. In most locations, these routers are LonMark-certified devices that will need to be replaced with any new control work. Contact the DEN Mechanical Engineer for a copy of the latest router location map.

Facilities outside of the CUP are being converted to communicate to a common Johnson Controls Inc. Metasys Control System (EMCS). All renovations, building expansions, and new buildings that are maintained by DEN maintenance personnel shall be connected to this control system.

Currently, the Terminal, AOB, Concourse A, Concourse C, and various outlying buildings use an aging Honeywell CNAP controls system. CNAP controls are no longer supported by Honeywell, and new and replacement parts are not available. Additionally, Honeywell will not support connecting additional CNAP VAV/FPB controllers (mcels) to the CNAP AHU controllers (xl-plus boards). Due to their volatility and lack of replacement parts, DEN will not allow additional VAVs or FPBs to be added to AHU systems that still use the xl-plus controllers. When designing mechanical systems in these areas, designers should re-use existing mcels already connected to the xl-plus boards. If additional VAVs or FPBs are required, the xl-plus board must be replaced with new BACnet-compatible controllers. Wherever xl-plus boards are replaced, all VAV controllers (mcels) and any other devices connected to the xl-plus boards and associated controls cabling must also be replaced with new BACnet-compatible controllers and cables. All associated terminal control devices (temperature sensors, thermostats, duct static pressure sensors, etc.) must also be replaced with BACnet-compatible devices. Contact the DEN Mechanical Engineer when designing mechanical systems in the areas listed above for current controls-based restrictions.

The fire and security automation systems are independent and separate systems from the HVAC automation system.

5.0.3 New and Replacement HVAC Control Systems

For continuity of operation of the controls systems at DEN, HVAC DDC controls systems are limited to systems manufactured by Johnson Controls, Inc., Automated Logic Corporation, and Alerton. Consult DEN PM and DEN Mechanical Engineer for existing controls system in the area of work.

Work associated with equipment in the Central Plant (CUP), Concourse Pump Rooms, Terminal Pump Room, and the AOB pump room is to be Johnson Controls, Inc. for direct integration into the EMCS system. Remove any existing Honeywell and Automated Logic Corporation controls for existing equipment to remain in these areas and replace with Johnson Controls for direct integration into the EMCS. Update the existing equipment’s Sequence of Operation as needed for control replacement.

Design each network of the DDC system to include at least 30 percent available spare bandwidth with the DDC system operating under normal and heavy load conditions. Calculate bandwidth usage and apply a safety factor to ensure that this requirement is satisfied when subjected to testing under worst-case conditions. Do not use an existing network controller that is at 70 percent capacity or greater. If DDC equipment is added to a controller which is below 70 percent capacity, it must not exceed 70 percent capacity once the equipment is installed. Reference the Communication & Electronic Systems DSM for more information.

Include spare processing memory for each new or replacement controller. RAM, PROM, or EEPROM will implement requirements indicated with the following spare memory:

A. Network Controllers: Not less than 30 percent spare capacity.
B. Programmable Application Controllers: Not less than 30 percent spare capacity.
C. Application-Specific Controllers: Not less than 30 percent spare capacity.

New and replacement DDC Controllers shall include 20 percent spare I/O point capacity of each AI, AO, BI, and BO point. The minimum spare I/O Points per controller shall be:

A. AIs: Three
B. AOs: Three
C. BIs: Five
D. BOs: Five

All trend data shall be stored on an SQL database accessible by DEN staff.

All EMCS front-end Graphics shall be MUI (MetaSys UI) compatible. Views and points for all areas shall be imported into MetaSys.

5.1 Control System Instrument Air

5.1.1 General

Independent instrument air systems are present in the CUP, terminal, and each concourse. These systems are largely undocumented and should not be used for building expansions or renovations. All new control devices shall be electrically operated/actuated. The information below is for historical design reference only.

Compressed air is generated from a centralized compressed air facility with oil-free reciprocating or screw-type compressors. Because of the critical nature of this system, there is one operational system with at least one standby system under all circumstances. This means that if one system is down for maintenance, there will be one system in operation and one additional system as a standby for a minimum of three systems.

The main distribution system air pressure is 80 to 100 psig with pressure-reducing stations to reduce the pressure to the respective usable levels for temperature control systems. The main control air is dried with externally heated, regenerative air dryers to a -40°F dew point to prevent airlines from freezing ambient air temperatures. The dryers have adequate filters located both before and after the dryer. The dryers are interlocked to operate with their respective air compressors.

5.2 Sample Control Components and Requirements

5.2.1 AHU Controls

A. Provide economizer controls to utilize free cooling when possible during mild weather.

B. Variable volume control should be monitored from reliable static pressure control sensors located approximately two-thirds of the total duct length downstream of the air unit supply fan. Static pressure sensors shall be placed in a position such that the controller setpoint is no greater than one-third of the total design fan static pressure, or the static pressure setpoint shall be dynamically reset. Static pressure sensor shall be located on plan documents and have dedicated access for maintenance/calibration.

C. Provide control logic to permit reduction in ventilation (outside air) requirements at night and during any extended off-peak periods that can be determined. (The specified ventilation rate is the minimum condition required at peak occupancy; this condition will occur infrequently.) This functionality shall be achieved by using occupancy and/or CO_2 monitoring controls.

D. Provide control elements required by code and for efficient AHU operation (i.e., smoke detectors, freeze stats, etc.) in addition to the items just described. In general, AHUs shall have the following:

   a. Outdoor air temperature
   b. Mixed air temperature (entering unit)
   c. Supply air temperature
   d. Supply air flow
   e. Hydronic coil inlet and outlet temperatures (fluid)
   f. Filter air pressure drop
   g. Coil air pressure drop
   h. Coil control valve position
   i. Hydronic coil flow rates (CW and HHW)
   j. Fan status
   k. Motor runtime
   l. VFD speed percentage (as applicable)
   m. Control damper positions
   n. Supply duct static pressure
   o. High limit static pressure alarm (at unit, not downstream in a duct)

E. Provide an adjustable non-averaging element freezestat to be mounted on the downstream side of every heating coil section arranged to stop the supply fan (and return air fan as applicable), close the outside and exhaust air dampers, and open return air dampers when any one-foot section of the element of the freezestat senses a temperature below the setpoint (36°F).

   NOTE: Freezestat controls shall be prevented from shutting down any air unit when it is operating in a smoke removal mode. No equipment is to be provided that could shut down a unit fan when it is operating in a smoke removal mode.

F. Provide airflow measuring stations and install them on the discharge of each supply fan, on the intake duct for any return air fan installed, and on the outside air duct for each unit. This is to provide ventilation airflow rate monitoring and fan tracking control between the supply and return air fans where used.

G. Provide override control to reset the outside air dampers during extreme weather or in emergencies.

H. In the event of a power loss, the AHU outside air dampers shall fail to the fully closed position. Return Air dampers shall fail to the fully open position. Heating Hot Water control valves shall fail to the fully open position, and Cooling Water control valves shall fail to the fully closed position.

5.2.2 VAV Terminal Unit Controls

A. Zone temperature controls shall be designed to have a 5°F space temperature setpoint deadband between heating and cooling operation.

B. In general, VAV controls shall be selected and configured for proportional control and not floating point control. Designers shall discuss any concerns (e.g., first cost impacts) or recommended deviations with a DEN Mechanical Engineer.

C. VAV boxes with heating coils control shall be provided with a discharge air temperature sensor to be located downstream of the VAV box for temperature setpoint reset control.

D. VAV box controls shall prohibit reheat or simultaneous heating and cooling operations per ASHRAE 90.1.

E. Where reheat is required due to existing system limitations, the system may be designed to comply with the exceptions to ASHRAE 90.1 reheat restrictions. In these cases, reheat shall be minimized to the extent possible. Refer to 5.2.8 HVAC Control Functions.

5.2.3 Unit Heater Controls

Small unit heaters shall be controlled by cycling the fan on and off and controlling a two-way valve on the hot water coil. Large unit heaters shall run continuously while heating is required, and water flow to the coil shall be modulated to maintain the set space temperature. All modulating control valves shall be pressure-independent type.

5.2.4 Split Systems – Fan Coil Units (FCU)

Where split systems are installed in critical spaces such as telecommunications and electrical rooms, the Facilities EMCS shall monitor the status of the fan coil unit fan and air-cooled condensing unit with the use of a current transformer and shall alarm the system in the event of a fan or compressor failure. The EMCS shall also monitor the room temperature. The fire alarm system shall stop fans. The split system shall run through factory controls based on the room thermostat.

Hydronic FCUs shall be utilized where design conditions permit. Small unitary FCU installations shall use 2-position control valves for hydronic coil control. Larger or multi-zone FCUs, or designs requiring finer flow control (e.g., for discharge temperature setpoint control) shall use modulating control valves. All modulating control valves shall be pressure-independent type. Hydronic control valves shall be located on the downstream side of cooling/heating coils.

In the event of a power loss, the FCU outside air dampers shall fail to the fully closed position. Return Air dampers shall fail to the fully open position. Heating Hot Water control valves shall fail to the fully open position, and Cooling Water control valves shall fail to the fully closed position.

5.2.5 Exhaust Fan

In general, exhaust fans should be interlocked with the building AHU and run continuously.

5.2.6 Pump Controls

Hydronic system pumps shall be selected to operate at variable speeds and shall be provided with all necessary control devices, variable speed drives, and inverter duty motors to allow variable speed operation. Variable frequency drives shall be capable of independently logging and storing operating data, including speed (expressed as a percentage of maximum), run time, and instantaneous power consumption (kW). Small constant-speed pumps may be used for long runs, but these applications shall be limited and require approval from a DEN Mechanical Engineer.

Heating and cooling coils shall not utilize pumped coil loops for freeze protection. Pumped loops for waterside economizers shall not be used unless previously approved by a DEN Mechanical Engineer.

Sump pumps shall be controlled by float level. The Facilities EMCS shall monitor sump pumps for status, run time, and alarm only.

5.2.7 Monitoring

Fire system monitoring or security provisions are not incorporated into the EMCS initially; however, provisions should be made to allow these features to be added should this requirement change.

5.2.8 HVAC Control Functions

The AHUs and the spaces they condition shall be controlled by standalone, remote, automation control systems. These systems shall be located directly in areas of equipment. The microprocessor-based control system shall communicate with the EMCS through an Ethernet port interface via BACnet communication protocol and all other necessary equipment for proper signal-level reception and transmission.

The following control functions shall be programmed into the control system:

A. Provide airside economizer controls to utilize free cooling when possible on all AHUs with a design capacity greater than 54,000 Btu/h (or current ASHRAE 90.1/IECC requirements, whichever is more stringent).
B. VAV boxes are to be controlled by the temperature control system. The controller shall adjust the box's damper position based on the space temperature. VAV boxes with heating coils shall also reset discharge air temperature in a heating mode based on the space temperature signal.
C. The total supply air volume shall be controlled by static pressure sensors located in the main supply air duct. The supply fan's motor speed controller shall be modulated to maintain the duct static pressure setpoint.
D. Variable air systems that have heating coils at the VAV terminal units shall be designed to control to the following sequences/reset schedules unless a clear need is demonstrated and alternate control sequence is approved by DEN Mechanical Engineer. Reset control examples are presented below. The engineer shall review the validity of the examples for use in design on a unit-by-unit basis. (For example: XO-123 requires City Spaces to have a VAV cooling setpoint of 78°F.).

5.2.8.1 AHUs

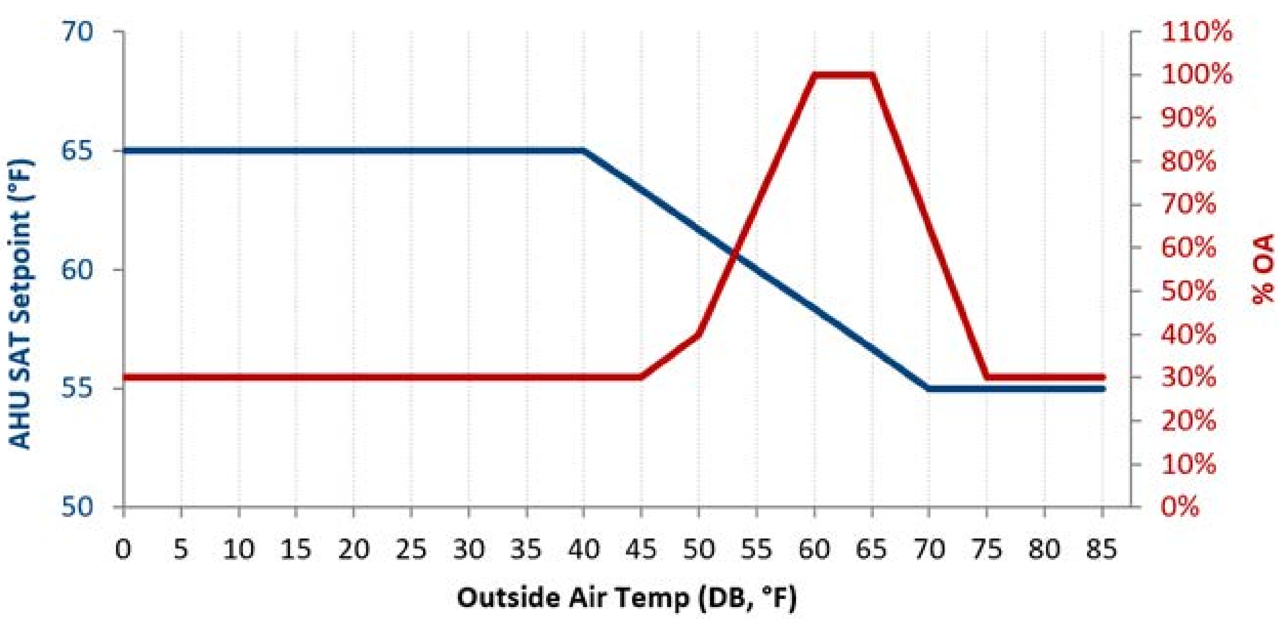

Figure 5-1: Figure 5-1: AHU Control

5.2.8.2 VAV Boxes

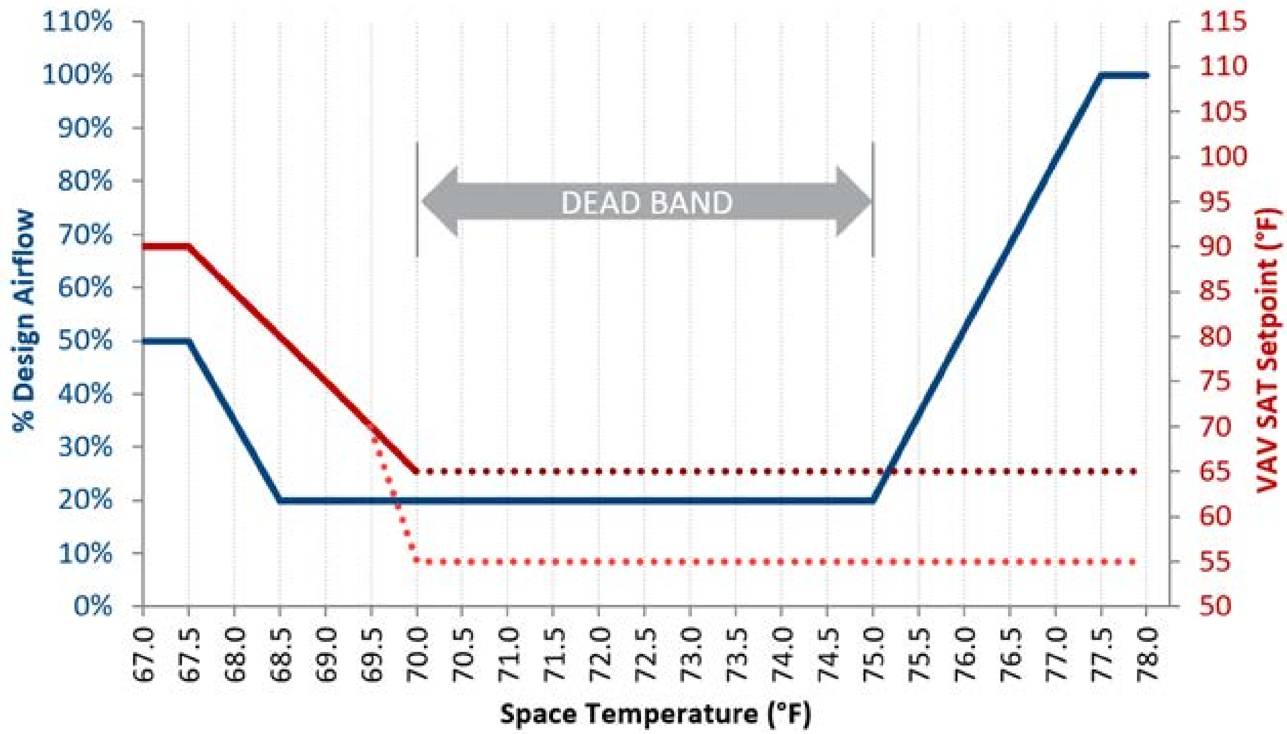

Figure 5-2: VAV Control

NOTE: Designs may require alteration of the minimum percent Design Airflow and/or percent OA setpoints shown above (indicated as 20% and 30%, respectively) for zones or AHUs to meet code-required minimum ventilation rates. Conversely, designs utilizing Demand Control Ventilation may warrant a reduction of these minimum setpoints.

5.2.9 Thermostats and Temperature Sensors

Thermostats are only allowed on unitary equipment that is not connected to the EMCS. Temperature sensors shall be provided in all other locations. All new temperature sensors shall be furnished with a service port for remote laptop connection to the unit controller and EMCS.

In areas of the airport accessible to passengers, thermostats and temperature sensors shall not have displays.

5.2.10 Carbon Monoxide Sensors

Carbon monoxide sensors shall be provided in the service drive or wherever internal combustion engine traffic is utilized in an enclosed space. Sensors shall increase airflow and/or alarm out-of-tolerance conditions.

5.3 Central Control Systems for Main Airport Buildings

The EMCS consists of a central host computer, including an IBM-PC/AT computer (or compatible) with a VGA/color monitor. This host computer is in the CUP, and standalone remote system controllers shall be located in the areas under control. The EMCS shall be a user programmable, all-electronic, digital control system. The central host computer shall have, as a minimum, an EGA/color monitor, printer, alarm printer, mouse (or ball), and storage and shall consist of all necessary components to provide communications to the field panels. This shall be a comprehensive system and shall be coordinated with all other ongoing projects at the airport that will be tied to the EMCS.

NOTE: All new field controllers and panels outside of the CUP shall be BACnet-compatible devices and must be able to interface with the Facilities EMCS. All controllers and devices in the CUP shall be designed to interface via BACnet IP with Johnson Controls Metasys EMCS (the CUP EMCS) that was installed in 2014.

5.3.1 Software

The EMCS shall have all software necessary for real-time monitoring, program loading/editing, report generation, and data acquisition. The software shall be programmed to display color graphic screens of the areas and systems controlled and provide operating reports, trend logs, energy consumption, analysis capability, and alarm reports. The software shall display actual operating conditions on the graphics display screens. Software should be non-proprietary and reprogrammable by the user. Source codes, custom programming, custom graphics, etc., shall be provided to the owner along with a duplicate set of backups. The Design Consultant shall review the current stage in the development of the universal protocol and make every practical effort to incorporate this into the temperature control automation system.

The software shall have the following capabilities:

A. Run time
B. Optimum start/stop
C. Economizer controls
D. Load shedding
E. Time of day scheduling
F. Chilled water outdoor air reset
G. Hot water outdoor air reset
H. Variable condenser, hot, and chilled water pumping (to optimize hp vs load)
I. Night set back
J. Status
K. Change of status
L. Smoke venting and control
M. Ambient high/low alarms
N. Energy totalizing
O. Maintenance and alarm reports
P. Heating/cooling mode
Q. Electrical system monitoring, as outlined in the electrical design standards

5.3.2 Graphics Capabilities

The central computer terminal shall have a dynamic color graphic display programmed for each air handling system, secondary pump room, and the areas being monitored and controlled. Any project that requires modification of building controls shall include specifications for the replacement of the system graphics with the most current templates. When new control graphics are introduced, all previous versions of controls graphics shall be removed.

5.3.3 Trend Logging and Graphing

Trend logs and graphing capability shall be provided. All new control applications and/or any project that requires modification of building controls shall require that trend data be set up for all major AHUs and pumps. Trending data that is automatically uploaded to the controls data server must be programmed at a coordinated time to minimize network traffic during the data transfer. Include noting in the construction documents to coordinate such timing with the EMCS administrator.

5.4 Sequence of Operation

The startup, operation, and shutdown of systems shall be sequenced in accordance with the general control sequences outlined in the Technical Specifications of the Mechanical Design Standards. Prior to the installation of a specific system, a specific and more detailed sequence of operations shall be developed for each type of HVAC, HV, or ventilation system. In these sequences of operation, specific points of measurement of temperature, humidity, pressure, etc., shall be designated.

Designer is to ensure accuracy of the Sequence of Operation and coordinate with any existing systems and equipment. Designer shall research and coordinate with the appropriate stakeholders until a thorough understanding of how existing systems and equipment operate. Construction documents are to include the integration of new and existing equipment operation into the Sequence of Operation.

5.4.1 Emergency Shutdown

Operating facilities with potentially explosive, toxic, or otherwise hazardous processes shall be equipped with emergency process shutdown panic buttons located at the main control panel and at all exits to the affected areas. Each HVAC system shall have a manual shutdown button per National Fire Protection Agency (NFPA) 90A located at a firefighter's emergency shutdown station.

5.4.2 Automatic Shutdown

Each HVAC system with 2,000 cfm or more capacity shall be equipped and arranged to automatically shut down fans (and close dampers on units larger than 15,000 cfm) in accordance with NFPA 90A, Denver Building Code Amendments, and initiate the fire alarm. Smoke detectors installed in HVAC ductwork shall be tested prior to acceptance for proper airflow and voltage sensitivity in the presence of the Project Engineer. The shutdown circuit shall prevent the AHU from restarting until the smoke detectors have been reset by DEN's fire protection personnel. This test for proper operation shall be made with the AHU in all modes of operation.

Those units that are to be used for smoke removal shall be arranged such that no control function can shut down the unit fan and override the smoke removal function when activated.

5.5 Controls Points Naming

5.5.1 General

Controls points in the EMCS front end shall be named in a consistent and informative way. Every point name shall indicate the equipment it is associated with and the function of the point itself. Each point name shall consist of the entire equipment tag, described in 1.2 Equipment Identification, and a standard abbreviation describing the function of the point. A list of all standard abbreviations used by DEN can be found in non-standard abbreviations must be approved in writing by DEN Mechanical Engineer.

Each point name must be unique. Because of this, smaller terminal equipment with non-supervisory controllers must include the abbreviated equipment name from their supervisory controller in their point names. Refer to 5.5.3 Non-supervisory Controller Point Naming.

IP addresses for BACnet and LonWorks routers are not available to the public. Written approval from the DEN PM, DEN Mechanical Engineer, DEN Manager of Systems, and DEN Information Security is required to access this information.

5.5.2 Supervisory Controller Point Naming

Naming for supervisory controller points shall include the name of the equipment associated with the point, followed by an abbreviation of the function of the point. A period shall separate the equipment name from the function abbreviation.

LLL_XX_LX_LLL_L(L)(_XX)	_	LLL	.	Abbreviation
(1)		(2)		(3)

L = Alphabetical character
N = Numerical character

For example, the point name for the discharge air temperature for AHU-B in the 4th floor mechanical room of Holdroom 7 West of Concourse B would be CCB_04_7W_AHU_B_TCP.DA-T. The effective discharge air temperature setpoint for the same unit would be CCB_04_7W_AHU_B_TCP.DAT-EFF-SP.

5.5.2.1 Equipment Tag

The first component of the point name shall be the equipment tag, as defined in 1.2 Equipment Identification.

CCB_04_7W_AHU_B	_	TCP	.	DA-T

5.5.2.2 TCP Extension

AHU control panels are all tracked as separate sub-assets in the DEN Asset Management Program from the AHUs they control. Because of this, the abbreviation _TCP shall be added to the end of the equipment name when naming AHU control points.

CCB_04_7W_AHU_B	_	TCP	.	DA-T

5.5.2.3 Function Abbreviation

The third component of the point name shall be the function abbreviation. A period shall separate the first three components of the point name from the function abbreviation. Abbreviations can be found in Appendix A – Controls Points Abbreviations.

CCB_04_7W_AHU_B	_	TCP	.	DA T

5.5.3 Non-supervisory Controller Point Naming

Due to the sheer number of non-supervisory controllers at DEN (e.g., terminal device controllers such as VAV or UH controllers), additional information must be included to ensure each control point name is unique. Points for non-supervisory controllers will have four components as follows.

LLL_XX_LX_LLL	_	XXXLLL(L)	_	XX(L)	.	*Abbreviation*
(1)		(2)		(3)		(4)

L = Alphabetical character
N = Numerical character

For example, the point name for the occupied heating setpoint for ATH-05, located on the Mezzanine Level of Subcore 6 West of Concourse B, served by AHU-B in the 4th floor mechanical room of Holdroom 7 West would be CCB_03_6W_VAV_047WAB_05H.OCC-HTG_SP. The discharge air temperature for the same unit would be CCB_03_6W_VAV_047WAB_05H.DA-T.

5.5.3.1 Equipment Tag

The first component of the point name shall be the equipment tag, as defined in 1.2 Equipment Identification. The numeric designator shall be removed from the equipment identification.

CCB_03_6W_VAV	_	047WAB	_	05H	.	OCC-HTG-SP

5.5.3.2 Equipment Controlled

The second component of the point name shall identify the equipment that the supervisory controller controls. This shall be an abbreviated version of the equipment tag for the supervisory controller's equipment. The building identifier shall be removed, along with all the underscores. The equipment abbreviation shall be shortened to the first letter of the abbreviation.

For example, the shortened abbreviation for AHU B located in the 4th floor mechanical room of Holdroom 7W of Concourse B would be shortened from CCB_04_7W_AHU_B to 047WAB.

CCB_03_6W_VAV	_	047WAB	_	05H	.	OCC-HTG-SP

5.5.3.3 Numeric Designator

The third component of the point name shall be the numeric designator of the equipment. The first 3 components of the point name shall be separated by underscores. In instances where there would be two sequential underscores, only a single underscore shall be used.

CCB_03_6W_VAV	_	047WAB	_	05H	.	OCC-HTG-SP

5.5.3.4 Function Abbreviation

The fourth component of the point name shall be the function abbreviation. A period shall separate the first three components of the point name from the function abbreviation. Abbreviations can be found in Appendix A – Controls Points Abbreviations.

CCB_03_6W_VAV	_	047WAB	_	05H	.	OCC HTG SP

End of Chapter

Chapter 6 - Hydronic Systems

6.0 Hydronic Systems

6.0.1 Existing Campus Heating/Cooling Systems Operation

Chilled water and heating water for the HVAC systems in the terminal buildings, AOB, and concourses are supplied from the CUP. Refer to Chapter 2- Central Utility Plant for overall systems and additional requirements.

6.1 Equipment

6.1.1 Chilled Water System

The chilled water system for the terminal complex is configured in a primary-secondary arrangement. The first loop is the primary loop, which shall use chiller pumps in parallel and headered to circulate water through the chillers that are piped in parallel.

The pumps shall be connected in parallel on suction and discharge headers with a 1-to-1 ratio of chiller pumps to chillers. Pumps shall modulate speed to maintain flow through the operating chillers and around the primary loop. Under no circumstances shall the chilled water pumps deliver flow below the minimum allowable flow to an operating chiller. The chiller loop must be arranged to easily adapt additional chillers and chiller pumps for future capacity requirements.

The distribution loops are labeled secondary loops and are variable flow systems. The primary loop distributes the chilled water from the chillers to the terminal building, concourses, and other buildings and areas to be served with cooling, where secondary pumps in parallel supply the secondary distribution piping with chilled water.

The secondary pumps shall be modulated and staged based on static pressure at the most hydraulically remote point of the critical circuit of each secondary distribution loop. The EMCS shall cycle the primary loop pumps to match the combined system load of the secondary loops by maintaining a slight positive flow (approximately 1-2%) in the decoupler line between the primary and secondary loops.

Flow measuring devices will be required in each loop and subcircuit, as well as the decoupler.

No glycol is used in this system.

The DEN chilled water system shall not be used as condenser water for direct-expansion-unitary-type HVAC or refrigeration equipment without written approval from the Manager of DEC Systems Group. The only exception not requiring approval is low-temperature systems serving the PCA glycol system.

6.1.2 Heating System

In the Hotel/PTC only, DEN identifies hot water system temperatures and pressures as follows:

A. Low-temperature hot-water heating system: This hot water system operates within a temperature of 250°F. The maximum allowable working pressure for a hot water system is 150 psi. All the hot water hydronic systems connected to the CUP system meet this criterion.

B. Medium temperature hot-water heating system: This hot water system operates at a temperature of 350°F or less. The maximum allowable working pressure for this type of hot water system is 150 psi. The medium-temperature hot-water heating system is not currently in use at DEN.

C. High-temperature hot-water heating system: This hot water system operates at temperatures exceeding 350°F. The maximum operating pressure for this type of hot water system is less than 300 psi. The high-temperature hot-water system is not currently in use at DEN.

Heating in all building spaces shall be provided by hot water from hot water generators (boilers) located in the CUP. The hot water system will consist of a boiler circuit or loop, a primary hot water distribution system loop, and a secondary distribution system loop serving the terminal units. Hot water boiler pumps shall be equal in number to the boilers and shall circulate and maintain a constant temperature in the boiler loop (reset with outside temperature). The primary loop will consist of pumps in parallel supplying a variable flow, as required by the demand and differential pressures, to the secondary loops. Based on final facility and system considerations, more than one primary loop may be justified. The secondary loop pumps shall provide a variable flow sufficient to maintain a differential pressure between the supply and return legs of the most remote unit on the secondary loop.

Flow measuring devices are required in each loop and subcircuit, as well as the decoupler.

Provide one stand-by pump for each loop system. No glycol is used in this system.

6.1.3 Hydronic Requirements

Chilled or heating water shall be sized for a maximum of 10 feet pressure drop per 100 feet of equivalent pipe for any run, but no more than an average of 4 feet pressure drop per 100 feet of equivalent pipe for the entire connected system. Circuit setters or balancing valves shall not be used for equipment isolation. Chilled Water coils shall be selected for a 16°F ΔT and Heating Water coils for a 40°F ΔT, at the following conditions:

A. Hydronic design temperatures for primary loop:
    a. Chilled water supply temperature: 42°F with reset controls in cooler conditions potentially allowing up to 50°F
    b. Chilled water return temperature: 58°F (will vary)
    c. Heating water supply temperature: 220°F
    d. Heating water return temperature: 170°F (will vary)
    e. No glycol is used in the DEN primary loops
B. Hydronic design temperatures for secondary loops:
    a. Chilled water supply temperature: 42°F with reset controls in cooler conditions potentially allowing up to 50°F
    b. Chilled water return temperature: 58°F (will vary)
    c. Heating water supply temperature: 190°F
    d. Heating water return temperature: 150°F (will vary)
    e. No glycol is used in DEN secondary loops. Glycol systems only exist on secondary or tertiary loops when used in conjunction with a heat exchanger.

Design Consultant shall review system designs to ensure chilled water temperatures in secondary systems do not exceed 58°F. Temperatures in excess of 58°F cause problems with the operation of PCA plant equipment.

Design shall ensure that the minimal pipe length is achieved, and no unnecessary loops or branches are used. Piping shall be routed in the most direct route feasible.

Designs including flow meters or other devices requiring servicing shall be located such that access to these devices is below 10'-0" AFF.

Flexible hydronic piping shall not be used in heating and chilled water hydronic systems.

6.1.4 Tenant Loops

When not defined in the record documents, no more than 20 GPM of chilled or heating water shall be used for any Tenant in the existing Concourses. Connections shall only be made to the base building Tenant hydronic loops when they exist. Tenant loop connections are located at each central core and concourse subcore on the apron level. Other locations will be approved in writing by the DEN Mechanical Engineer on a case-by-case basis with supporting system flow analysis. Systems shall not be deemed to have adequate capacity for connections at any location there is not an existing valved connection.

When tenant spaces are designed for future use (e.g., grey box) with no terminal equipment installed and connections for future systems are provided, the final contract documents shall indicate the maximum allocated water flow (gpm) and design pressure (PSIG) for each connection in each space.

For any new Tenant service, a digital BTU meter on each hydronic service entrance to the Tenant lease area shall be installed. The meter shall be in an accessible area within the Tenant lease area. The meter shall have native BACnet communication and connect directly to the DEN EMCS.

6.1.5 Piping and Valves

Piping, for both the CUP and the distribution systems, shall be designed to minimize pressure losses and maximize energy use efficiency. Valves to be specified for equipment servicing shall be selected to minimize losses while open and have suitable pressure drop characteristics for the intended use. The piping shall be designed to allow for CUP equipment expansions.

Control valves shall be sized for the correct and appropriate Cv value at the design flow rate. All valves shall be suitable for extended service operation without extensive requirements for lubrication or servicing. Control valves shall be pressure-independent valves manufactured by either Flow Control Industries Delta-P Valves or Johnson Controls VP140 series valves. Valves and actuators used on the CUP distribution side (230°F heating water temperature) are to be rated for a minimum of 250°F; valves and actuators on the building side (190°F heating water temperature) are to be rated for a minimum of 212°F.

Many of the existing butterfly and ball valves no longer positively close and seal. Designer to anticipate that valves 2-1/2" and larger that are original will need to have line stops installed and the defective valves replaced. Verify location with the DEN Mechanical Engineer.

Tees, valves, paddle blind, and blind flanges shall be provided to allow for additions of equipment and piping to the CUP or any piping mains without the interruption of services. If a piping main must be taken out of service for any means, a bypass shall be designed into the system to avoid an extended outage. Paddle blind flanges are to be temporarily installed at connections to existing systems to prevent water from inadvertently entering the new systems. Piping systems shall be sized for ultimate loads. Tees, valves, and blind flanges shall be provided on distribution piping systems for the expansion of distribution systems; sectional valves shall be provided in the distribution piping for piping system repairs and at key locations to provide isolation and servicing of equipment. On compressed air lines, quick disconnect connections shall be installed downstream of sectional valves to enable the use of portable compressors in emergencies. The piping design and materials selection shall be in accordance with ANSI/ASME Standard B31.9 Building Services and ANSI/ASME Standard B31.1 Power Piping.

Mechanical grooved piping and fittings shall not be used for hydronic systems and should not be considered for value engineering options. Due to the operating system temperatures and system movement, mechanical grooved connections have been problematic for maintenance.

Flanged connections are allowed only at valves and connections to equipment (pumps, coils, etc.). Flanged connections shall not be used in other locations.

No piping shall be routed through/across the AGTS tunnel.

Isolation valves are required at all equipment and branches. Ball valves, gate valves, or butterfly valves should be rated for the temperature and pressure of the line. Valves shall be added before and after any control valves, strainers, air vents, coils, etc., for service. Equipment in series with no branches may all be isolated by a single pair of isolation valves.

6.1.6 Pumps

Pumps shall be selected for maximum operating efficiency (i.e., slightly to the right of the maximum efficiency point on the pump curve). Single pumps to be used in throttling applications without variable speed drives shall have relatively flat performance curves and be selected for operation on the pump performance curve to the right of the point of highest efficiency. Multiple pumps for parallel operation shall have relatively steep performance curves. Multiple pumps for series operation shall have relatively flat performance curves. Pumps for variable speed drive applications shall have relatively steep performance curves. All pumps shall be specified with suction and discharge flange taps for pressure gauge connections. Include high performance shaft seals in pump specification for system being used and a spare set for each pump.

The final selection of pump types and the application arrangement shall be made to maximize pump efficiency without excessive initial pump costs. All pumps that are selected for both current and future needs will be sized for future requirements, where practical, and equipped with the necessary accessories. The lower initial performance requirement will be met by balancing valves or by using a trimmed impeller to provide energy-efficient operation in start-up performance.

Standby pumps and accessories shall be provided for both heating and cooling systems. Pumps shall be arranged in a parallel configuration and headered to maximize pumping flexibility.

In general, vertical turbine pumps shall be used for pumping cooling tower water. Hydronic water applications shall use end suction pumps for flow rates below 500 GPM. Horizontal split case; double suction pumps shall be used for flow rates above 500 GPM.

Vertical split case and double suction pumps will be allowed for use with flow rates above 500 GPM only in existing rooms when adequate space for horizontal arrangements does not exist.

High RPM pumps (>1750 rpm) should only be used when no other alternative exists.

6.1.7 Motors

Electric motors shall conform to NEMA Standards. All 3-phase motors shall be of premium efficiency type or greater. Motors shall not be selected for operation in the service factor range. The minimum system installed power factor shall be 90%, with a goal to attain a 95% system power factor. Motors larger than 15 hp shall have power factor correction.

Motors shall be specified to be provided with adequate thermal protection, integral or external control, branch circuit protection, and starters suitable for use with the motors. Motor and starter types shall be selected to minimize voltage fluctuations and current surges. Motors and starters shall be provided with auxiliary contacts for control and operation interface with the central EMCS and any other control functions included.

All motors to be used with variable frequency drives shall be appropriately inverter-duty rated.

6.2 Design Criteria

6.2.1 General Requirements

Piping layout and sizing shall be done using the best practices to ensure minimum energy loss by thermal transfer and friction. The hydronic systems design shall be based on the following criteria:

A. Piping shall be designed in accordance with the technical criteria in other sections of this DSM. Water pipe sizing shall be based on the stricter of the two following parameters unless code requirements overrule:

Table 6-1: Water Piping Sizing

Pipe Size	Max. Velocity (fps)	Max. Pressure Drop* (ft per 100 ft pipe)
up to 2"	4	8.5
2-1/2" thru 6"	6	4.5
8" thru 12"	8.5	2.5
14" thru 20"	10.5 (14)**	2.5
24" thru 42"	11.0 (14)**	1.5

**Based on new, clean steel pipe*
***Number in parenthesis is velocity limit applicable to long straight runs where noise is not critical (such as pipe tunnels, etc.). Maximum pressure drop still applies.*

B. Due to availability issues and relative cost, 5-inch piping and valves shall not be used.

C. Pressure drops in piping systems shall be calculated to allow for aging and corrosion of the interior surface. Therefore, all water piping systems shall be designed with the following friction factors (C values) based on the Hazen-Williams Friction Factor formula.

Table 6-2: Water Piping Friction Factors

System Type	C Value
Closed water	120
Closed, treated	130
Open water	100
(New clean steel pipe)	(140)

D. Hot and chilled water distribution systems should be designed for variable volume flow.

E. Hydronic systems should be designed for the widest practical ΔT and the closest possible approach of the return water temperature to the terminal equipment supply air temperature, but not exceed temperatures listed in this section.

F. The terminal equipment must be selected not only for its full load capacity but also for its performance over the full range of partial loads. Laminar fluid flow in the coils shall be avoided.

G. Integral face and bypass coils should be utilized with preheat coils.

H. Coils subject to 100% outside air at winter design conditions shall be protected by one of the following methods:

   a. Provide propylene glycol in the water loop serving the AHU coils for any unit with 100% outside air capacity at winter conditions. These units must not be equipped with protective override controls to shut off the fan if the freezing condition is determined when operating for smoke removal. The glycol-water loop for this system is to be linked to the main heating hot water system through a plate and frame-type heat exchanger.
   b. For those units not arranged for smoke removal use, provide freeze protection thermostats on the coil face to shut down the unit fan if a freezing condition is detected. Outdoor Air dampers shall fail closed.
   c. Pumped coils shall not be used as a means of freeze protection.

I. The impact of the change in volume due to the thermal expansion of the distribution system fluids during all operations must be addressed in the design process. Expansion loops shall be used to compensate for the impact of thermal expansion. Other methods of thermal expansion compensation shall only be allowed with written permission from DEN Mechanical Engineer.

J. Control valves in hydronic systems must not be oversized. The flow characteristics and pressure drops are to be selected for the appropriate Cv value corresponding to the design flow to be controlled.

K. Provide automatic air vents at all coils and at the high points of all piping. Provide drains at the low points of all piping.

L. Hydronic systems controls shall be automatic and adjustable to optimize pumping and thermal efficiency.

   a. When close control is essential, use two-way pressure-independent control valves.
   b. Three-way valves shall not be used on any system directly connecting the CUP hydronic system.
   c. When using three-way valves for throttling, avoid pressure under one port being significantly higher than under the other.
   d. Use mixing three-way valves with caution for flow diversion or diverting valves for mixing since the valves have tendencies to slam shut at reduced flows.
   e. Use two-way valves at terminal coils in variable flow systems.
   f. Hot water coil valves shall fail to the open position.

g. No coil or heat exchange device shall be run wild or without a control valve.

M. When designing piping supports, roller hangars, and supports shall only be used with written permission from DEN Mechanical Engineer.

6.2.2 Flushing and Cleaning for Closed Hydronic Systems - Metallic Piping Systems

A. Engineer to include methods for testing, flushing, and cleaning of metallic closed loop piping systems in the hydronic piping flow diagram. Include locations for the installation of slip bling and blind flanges or other appurtenances for isolating new piping and equipment from the old. On the contract drawings include methods for testing, flushing, and cleaning in the hydronic flow diagrams including any temporary valves, spool pieces, and a list of equipment that is not to be installed such that flushing can occur. Use multiple hydronic flow diagrams as necessary to convey this requirement; do not describe the requirements in the specifications without the use of flow diagrams. Do not use existing mechanical pumps or any of the hydronic water for filling. See Section 230400: Basic HVAC Requirements 3.01 FLUSHING AND CLEANING FOR CLOSED HYDRONIC SYSTEMS- METALLIC PIPING SYSTEMS in this DSM for requirements that need to be included in both the design and the specifications.

B. If external pumps are needed, include velocity and head requirements for the temporary pump that the contractor should use or rent.

6.2.3 Expansion Requirements

In modular buildings that are designed to be expanded as the airport capacity increases (such as concourses and the terminal) all hydronic systems shall be sized for the maximum build out of the facility. Piping flow diagrams shall indicate all calculated or assumed flow rates/capacities and pressures of all general spaces anticipated for future construction.

6.3 Piping Supports

6.3.1 Design

All piping supports shall be manufactured systems or designed and detailed by a Colorado Registered Professional Engineer. Supports shall be coordinated with Architectural and Structural disciplines and completely detailed for connection to the structure.

Under no circumstances shall the construction documents direct a Contractor to provide supports without detailed performance specifications outlining the criteria and requirements of supports and their design and installation.

6.3.2 Products

Cable or wire piping supports and/or anchors shall not be used.

6.4 Existing Systems

6.4.1 Hydronic Requirements

Hydronic heating and cooling availability varies from area to area in the concourse and Terminal. Many concourse sub-core locations contain tenant hydronic loops within the lease area. In general, these systems are sized for 20 gpm (heating and cooling) for each original lease area.

Existing heating water loops for perimeter VAV shall not be used for Tenant space conditioning without a complete heating water system analysis and verification of capacity. The analysis shall be accepted in writing by the DEN Mechanical Engineer.

The Tenant shall furnish and install a digital BTU meter on each hydronic service entrance to the Tenant lease area. The meter shall be in an accessible area within the Tenant lease area. The meter shall have native BACnet communication and connect directly to the DEN EMCS.

Provide isolation valves on the supply and return of each hydronic system serving the Tenant lease area. The valves shall be in an accessible area within the Tenant lease area.

6.5 Update of Standard Diagrams

6.5.1 Flow Diagrams

DEN currently maintains hydronic flow diagrams of all buildings, which shall be used on any project that modifies the hydronic arrangements in these facilities. These diagrams are being updated and may not be complete but are available from the DEN Mechanical Engineer. Consultants shall submit any modifications to these diagrams directly to the DEN Mechanical Engineer at the Issue for Construction and Record Documents phases of the project independently of any other required submittal.

All new flow diagrams shall be developed using the existing diagrams as guidelines. Consultants shall submit any new diagrams to the DEN Mechanical Engineer at the Issue for Construction and Record Documents phases of the project independently of any other required submittal. Submittals are to be in Revit; refer to the Digital and Facilities Design Standards Manual for specific BIM requirements.

End of Chapter

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Chapter 7 - Space Requirements and Maintainability

7.0 Space Requirements and Maintainability

7.0.1 General

Mechanical equipment and layout shall be selected to maximize equipment performance and minimize equipment servicing, repair, and maintenance. Equipment selection shall also consider durability, reliability, maintainability, and serviceability. Equipment arrangement and layout shall allow for safe and efficient accessibility for equipment removal, replacement, repair, and maintenance.

During the design phase, coordination with other design disciplines is essential to provide the necessary access to equipment. All otherwise inaccessible equipment and equipment components shall be provided with OSHA-approved catwalks, platforms, etc., to allow maintenance. The catwalks, platforms, adequate lighting, etc., shall provide for maximum safety to both personnel and equipment while allowing access for equipment maintenance. Standardization of equipment and materials shall be used to the maximum extent possible. Standardization and interchangeability will minimize the space and expense of the maintenance spare parts inventories. Items for consideration for standardization shall include but are not limited to, AHUs and components, terminal units, control components, heat exchangers, pumps, valves, and fans.

7.1 Design Requirements

7.1.1 Design

The design shall, in general, include equipment layouts with dimensioned maintenance and repair clearances indicated. Special maintenance items or equipment, or necessary auxiliary equipment shall be specified to be provided and installed with the equipment it is to serve. Avoid locating equipment requiring frequent service or repair above ceilings or in occupied spaces.

7.1.2 Equipment Selection

Equipment shall be selected for stable operation at both full and part-load conditions. Equipment selections shall be below maximum limits for capacity, speed, temperature, and pressure. The equipment installation design and specification shall include sufficient instrumentation for measuring, indicating, monitoring, operating, and servicing at full and part loads.

7.1.3 Bearings

Designer shall specify permanently lubricated bearings on fans, if available. Equipment that cannot be furnished with permanently lubricated bearings shall have lubrication lines extended to the exterior of the unit.

7.1.4 Construction Requirements

Designer shall require the Contractor to include in the shop drawing submittals the manufacturer’s recommended spare parts lists, maintenance and service clearances, special maintenance equipment or requirements, and recommended maintenance schedules. Conflicts between equipment and maintenance requirements or clearances shall be submitted, along with Contractor’s solutions to the conflicts, for approval. Approval of conflict resolution shall be required before equipment installation. Design shall require the Contractor to revise all flow diagrams, control diagrams, and additional information to reflect any revisions to designed systems and/or required performance capabilities to suit the actual equipment installed.

The design shall require the Contractor to provide instruction for operating personnel on the operation, attendance, and maintenance of equipment. Designs shall include all data necessary to establish an efficient and effective preventive maintenance program.

7.1.5 Fan Housing

All supply fan housings shall have ladder rungs mounted on the side of each unit next to the coil pipe connections to provide access to the top of each unit without stepping on insulated pipes.

7.1.6 Access Doors

All AHUs shall be equipped with access doors for each compartment (coils, filter, fan, etc.), with piano hinges, door handles, and a viewing window in each compartment access door. The doors should be sturdy enough to permit opening the door using one handle. Access doors shall seal airtight when closed to 6" WC positive static pressure. All doors and door swings shall be shown on the drawings.

Provide in accessible locations access doors of adequate size at all fire damper locations for inspection as well as for replacing fusible links.

All required access doors and door swings for every piece of equipment shall be shown on the drawings.

7.2 Space Requirements

7.2.1 Mechanical Rooms

Mechanical room space requirements and dimensions shall be coordinated with the architect so that appropriate space is provided for the equipment and its service and maintenance.

7.2.2 Mechanical Chases

Mechanical chase space requirements shall also be determined and coordinated, including space for supply and return air ductwork, outside ventilation air, exhaust air, hot and chilled water piping, domestic water piping, sanitary drainage, roof drains, etc. All chases with plumbing equipment shall have a minimum one-floor drain.

7.2.3 Equipment Clearance

Provide a minimum of four feet (clear space) around all sides of boilers and chillers, plus tube pull space. Provide a minimum of three feet (clearance space) around all sides of pumps and air handling equipment, plus coil pull space. All portions of equipment requiring replacement shall be fully coordinated with space layouts to ensure parts (coil pull areas, fan removal, gearbox, etc.) can be replaced without modifications to the space. These are minimum design requirements and shall be extended if the manufacturer’s requirements are greater. Knockout walls and removable sections of ductwork, etc., shall not be considered as a viable means of access for equipment maintenance access.

All rooftop equipment shall be serviceable through an existing roof access. Provide a minimum of three feet all around air handling equipment unless the manufacturer’s requirements are greater. Coordinate requirements for roof walkway/pads with Architect.

Drawings shall include dimension minimum clearances for all maintenance/service and access to equipment.

Where equipment maintenance requires overhead rails and/hoists, the entire access corridor shall be identified and dimensioned.

7.2.4 EMCS/Control Equipment Clearance

Provide a minimum of two feet (clear space) for maintenance in front of all EMCS and other control panels. For panels located above the ceiling, panel access shall be clear from the face of the panel all the way to the finished floor to allow for proper positioning of ladders. The maintenance area shall be indicated on the plans and models.

7.2.5 Equipment Removal Routes

All equipment and major components (e.g., fans, motors, VFDs, coils, dampers, etc.) shall be able to be removed from the equipment and space and hauled to a loading dock or exterior drive without the removal of doors or walls. Removal routes shall be a minimum of 36 inches clear and allow for floor transportation. In the event conduits and/or piping prohibit floor transportation, crane rails rated for the weight largest equipment component shall be provided to a location where floor transportation can occur.

7.2.6 Plumbing Chases

All restroom groups with more than four fixtures shall have plumbing chase. Chase shall be large enough to accommodate maintenance and replacement to/of all equipment (e.g., water heaters, expansion tanks, etc.) throughout the length of the chase. Minimum chase unobstructed width is recommended at 2'-6" unless approved in writing by the DEN Mechanical Engineer.

Plumbing chase shall be directly accessed from a City space. No chase access shall occur through janitor’s closets, electrical, or communications rooms.

7.2.7 Baggage System Right of Way

In certain areas, baggage conveyors will be routed through ceiling plenums and general spaces. The space requirement for these conveyors will be approximately 4 feet deep by 4 feet wide per conveyor, plus the additional space needed for personnel catwalks (preferably 4 feet wide). Therefore, all ductwork and piping must be routed to avoid conveyors and structural members. Physical space may prohibit ductwork/piping crossing baggage conveyors. Careful coordination is required.

Design Consultant shall coordinate with all systems and disciplines throughout the design process to ensure adequate space is available and to avoid interferences.

7.3 Equipment Protection

7.3.1 General

All equipment, ductwork, piping, and associated supports exposed to potential damage from vehicles shall have a form a structural protection. Protection shall be fully detailed in the contract documents and not inhibit or restrict equipment access requirements defined by this section. Structural protection shall be fully coordinated with required clearances for surrounding vehicles and service operations. Detailing of requirements by the contractor is prohibited.

End of Chapter

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Chapter 8 - Plumbing Requirements

8.0 Plumbing Requirements

8.0.1 General

This section applies to the systems used to receive, transport, or discharge liquid waste or sewerage; the systems used to receive and distribute potable water; the systems used to receive and distribute fuel gas; and the systems used for the collection and transport of rainwater and cooling coil condensate drains, etc.

8.0.2 System Requirements

A. Facilities for the physically disabled shall be provided in all public building restrooms.

B. Provision shall be made within the terminal building and each of the concourses for future expansion of the plumbing systems at such time that the complex is expanded to meet increased usage.

C. All domestic hot and cold water piping and designated storm drainage piping within conditioned areas shall be insulated. The Design Consultant shall use the best practices to ensure pipes do not freeze. Heat trace systems are not considered best practices and shall only be considered when no other option exists.

D. Buildings in the terminal complex and concourse areas shall be provided with roof drains and a drainage collection system. The roof drainage system shall be connected to the exterior storm sewer system. Overflow roof drain system shall be piped separately and terminated at grade level.

E. Structural roadways shall be provided with deck and curb drains and a suitable collection system.

F. An industrial waste sewer shall be provided for all liquid wastes that would be detrimental to the public sewer system or detrimental to the operation of a sewage treatment plant. Industrial waste shall be collected, treated, and disposed of as required by the authority having jurisdiction.

8.1 Plumbing Design Parameters

8.1.1 General

All plumbing systems shall conform to the requirements of the codes and standards listed in the Standards and Criteria DSM.

Projects required to have a Sewer Use and Drainage Permit (SUDP) require the engineer of record to perform site inspections and obtain photographic documentation necessary to verify installation conformance to the approved plans and specifications. Engineer is to submit documentation along with a cover letter signed and sealed from the engineer of record attesting to the installation and submit to the DEN Project Manager for Contract Director approval and submission to the Authority Having Jurisdiction.

8.1.2 Fixture Count

To determine the minimum number of fixtures required for the terminal and concourse areas, a plumbing fixture count method shall be used. The plumbing fixture method is a method of adjusting the number of people on which the number of fixtures is determined in setting the design for the plumbing facilities. After the number of people are appropriately adjusted, the fixture per persons for the type of building or occupancy from the uniform plumbing code shall be used for determining the minimum plumbing facilities.

The plumbing fixture method typically allows for additional fixtures for peak loads not adequately accounted for by the codes. The basis for the plumbing fixture count method is based on historical airport experience and the following criteria: (Design Consultant shall utilize these criteria or the CCD building code, whichever requires the higher number of fixtures.)

A. Projected Peak Occupancy (per area).

B. Thirty-three percent of passengers and 15% of visitors will use concourse facilities (departures and arrivals levels.)
C. Fifteen percent of visitors and 15% of passengers will use terminal building facilities.
D. The percentage of men and women in total occupancy is estimated at 55% male/45% female.
E. Each level and area shall be subdivided into terminal public space, restaurant, office, and retail to determine the fixture count for each particular occupancy.
F. Urinals shall be utilized in lieu of water closets in men's toilets to the maximum ratio allowed by the code.

Fixture counts and/or flow rates shall be shown on all isometric drawings.

8.1.3 Calculations

Design calculations shall be based on the latest editions of the ASPE Data Book, ASHRAE 90.1, and the Denver Amendments to the International Code Series. Recognized acceptable engineering practices shall be applied for areas where design criteria have not been established specifically by these codes and standards.

When using the International Plumbing Code (IPC) water fixture unit calculation method, only the flushometer table for conversion to flow rate shall be used since all concourse and terminal domestic water mains ultimately connect to public restrooms.

Several areas of the terminal and concourses experience dramatic pressure fluctuations. The engineer shall make every effort to ensure that new designs do not amplify current conditions. In these areas, static and dynamic pressure calculations shall be performed and submitted.

To avoid excessive system noise and the possibility of erosion-corrosion, flowrates shall not exceed flow velocities of 8 fps for cold water and 5 fps in hot water up to 140°F.

No assumptions shall be made on plumbing system capacities. All connections to existing plumbing systems shall have capacity calculations proving capacity. The design consultant shall submit all calculations directly to the DEN Mechanical Engineer in PDF format.

As of 2014, Denver Water maintains a domestic water supply pressure of 65 psi. This is 5 psi lower than the original airport system design.

8.1.4 Terminal

The terminal building plumbing facilities shall be designed for optimum passenger use and the total future terminal size to prevent under sizing of initial terminal building plumbing facilities.

8.1.5 Concourses

The plumbing facilities in the concourses shall be designed for the current initial passenger use. Expansion in concourse passenger service will be in conjunction with concourse construction expansions. Those expansions will include the necessary additional plumbing facilities. Plumbing utility systems (pipe sizes and arrangement) shall be designed to allow for future facilities expansion.

8.1.5.1 Concourse C West Expansion

As of 2014, the domestic water main serving subcore 3W and all spaces west are at the maximum design capacity. The Design Consultant shall conduct a full flow analysis and submit it to the DEN Mechanical Engineer prior to any modifications to this system.

8.1.6 Sand Traps

Sand traps and oil separators shall be installed for vehicle wash areas, deck and curb drains, and any other areas where sand and oil may enter the drainage system.

8.1.7 Grease Traps

Grease traps shall be required from fixtures and equipment with grease-laden waste located in food preparation areas. Grease traps are installed at all subcore of the concourses and many of the quadrants of the center cores. Two grease traps exist in the terminal, one serving each side of the facility.

As of 2014, the capacities are:

Table 8-1: Grease Trap Capacities

Tag	Building	Max Flow (gpm)	Capacity (gal)
A-18	Concourse A	100	2,500
A-24	Concourse A	100	2,500
A-31	Concourse A	100	3,000
A-38	Concourse A	100	2,500
A-39	Concourse A	100	2,500
A-40	Concourse A	100	2,500
A-41	Concourse A	100	2,500
A-49	Concourse A	100	3,000
A-71	Concourse A	100	2,500
B-12	Concourse B	100	2,500
B-22	Concourse B	100	2,500
B-28	Concourse B	100	2,500
B-29	Concourse B	100	2,500
B-37	Concourse B	100	2,500
B-39	Concourse B	100	2,500
B-44	Concourse B	100	2,500
B-45	Concourse B	100	2,500
B-52	Concourse B	100	2,500
B-53	Concourse B	100	2,500
B-80	Concourse B	75	1,500
B-88	Concourse B	75	1,500
B-63	Concourse B	100	2,500
C-27	Concourse C	100	2,500
C-30	Concourse C	100	2,500
C-31	Concourse C	100	2,500
C-39	Concourse C	100	2,500

Table 8-1: Grease Trap Capacities (Continued)

Tag	Building	Max Flow (gpm)	Capacity (gal)
C-38	Concourse C	100	2,500
C-41	Concourse C	100	2,500
C-40	Concourse C	100	2,500
C-48	Concourse C	100	2,500
C-49	Concourse C	100	2,500
C-54	Concourse C	100	2,500
C-57	Concourse C	100	2,500
C-62	Concourse C	100	2,500
C-63	Concourse C	100	2,500
T-East	Terminal	75	1,500
T-West	Terminal	75	1,500

As of 2016, flow/capacity diagrams have been developed to track system usage. These diagrams are available from the DEN Mechanical Engineer but are to be verified in the field for discrepancies in the area of work. Design Consultants shall submit any modifications to these diagrams directly to the DEN Mechanical Engineer at the Issue for Construction and Record Documents phases of the project independently of any other required submittal.

All new flow diagrams shall be developed using the existing diagrams as guidelines. Consultants shall submit any new diagrams to the DEN Mechanical Engineer at the Issue for Construction and Record Documents phases of the project independently of any other required submittal. Submittals are to be in Revit; refer to the Digital and Facilities Design Standards Manual for specific BIM requirements.

All grease traps shall be designed for a minimum retention time of 2.5 hours or sizing as required by Denver Wasterwater, whichever is greater.

Undersink/counter interceptors are not allowed when a grease waste line exists within a reasonable distance from the appliance. Undersink/counter interceptors shall only be used with written approval from the DEN Mechanical Engineer.

All grease interceptors (excluding allowed under sink/counter-type grease interceptors) shall be installed below grade. All manhole and cleanout covers shall be located at the grade or finished floor.

All grease interceptors shall be installed outdoors, except with written permission from DEN Mechanical Engineer. Any grease interceptors installed indoors (excluding allowed undersink/counter-type grease interceptors) shall be installed in rooms with exterior access doors.

Parking for interceptor grease removal vehicles shall be no more than twenty (20) feet from the furthest grease interceptor manhole. Vertical distance from the bottom of the grease interceptor to the grade level of the parking space shall be no more than twenty (20) feet.

Grease waste removal hose drag route shall not be through any public area except parking lots. Hose drag route may be through no more than one (1) door.

8.1.8 Floor Drains

Buildings shall be provided with floor drains that have traps and cleanouts.

Mechanical rooms shall contain general area floor drains and equipment drains for condensate and other miscellaneous drainage. Equipment drains shall not serve dual duty. Equipment drains shall be located to minimize pipe runs to the drain and minimize potential tripping hazards due to floor-supported piping.

All floor drains in chases, basement areas, restrooms, mechanical rooms, and entry vestibules shall have trap primers.

8.1.9 Cleanouts

Where a horizontal drainage pipe, a building drain, or a building sewer has a change of horizontal direction greater than 45 degrees (0.79 rad), a cleanout shall be installed at the change of direction. Where more than one change of horizontal direction greater than 45 degrees (0.79 rad) occurs within 40 feet of the developed length of piping, the cleanout installed for the first change of direction shall serve as the cleanout for all changes in direction within that 40 feet of developed length of piping.

The location and types of all cleanouts shall be noted on the drawing. All drains exiting the building shall have a double cleanout so that the drain line may be cleaned into and out of the building.

8.1.10 Industrial Waste

Industrial waste sewer shall be provided for areas where fueling of aircraft and vehicles takes place.

8.1.11 Backflow Prevention

The potable water supply system shall be designed, installed, and maintained in such a manner as to prevent contamination from non-potable liquids, solids, or gases being introduced into the potable water system through cross-connections or any other connections to the system. Protective measures and the requirement for backflow prevention devices shall meet or exceed the requirements of the IPC, Denver Building Code Amendments, and the requirements of the water utility, Denver Water. If there is any conflict between these requirements, the most stringent requirement shall apply in the design and/or modification to the existing potable water system. Should existing systems be found that do not comply with the latest backflow prevention requirements, the design will include upgrading the backflow prevention of that system being renovated, added to, and/or constructed. All domestic water connections to mechanical, plumbing, and fire protection systems, including lawn sprinkling systems, shall be protected from backflow by use of backflow preventers installed in the piping. Plumbing designs shall meet best management practices for cross-connection control.

At building or building zone main service entrances, provide two backflow preventers in parallel with lockable shutoff valves for primary and backup operations. Each backflow preventer shall be sized for full-service flow.

Separate backflow prevention is required on all potable water piping inside tenant spaces. Backflow prevention shall meet the requirements of IPC for backflow prevention. Single check valves shall not be used. Provide an isolation valve upstream of the backflow prevention device.

8.1.12 Coordination

It is the responsibility of the plumbing engineer/designer to provide design, specification, and detail of all plumbing connections to systems outside of the building (i.e., water, storm drainage, sanitary sewer, natural gas, etc.). The interface point shall note elevations (building reference and civil reference), sizes, and acceptable means of connection of differing materials and allowable tolerances of connection.

NOTE: Civil notes shall not be used to solely identify this connection.

8.1.13 Piping Movement

In underground piping systems subject to movement, ball and socket joint type flexible expansion joints (i.e., Flex-Tend) shall be used at connections to building piping. Semi-rigid elastomeric PVC couplings (i.e., Fernco) shall not be used. When exterior piping is encased in flowable backfill to the building face, flexible expansion joints are not required.

8.1.14 Future Tenant Spaces

When tenant spaces are designed for future use (e.g., grey box), the final contract documents shall indicate the following in each future space:

A. Valved and capped Domestic water connection identifying the maximum allocated water flow (gpm) and design pressure (PSIG).
B. Plugged sanitary connection identifying the maximum allocated drain fixture units (DFU).
C. Plugged sanitary vent connection identifying the maximum allocated drain fixture units (DFU).
D. (If applicable) Valved and capped natural gas connection identifying the maximum allocated flow (CFH) and design pressure (in WG).

8.1.15 HVAC Coil Condensate Drains

Coil condensate drains shall have properly sized condensate traps and shall be fully detailed in the contract documents. Condensate pumps shall only be used with written permission from the DEN Mechanical Engineer. General condensate drain trap details without a schedule of sizing are prohibited. Trap sizing by the contractor is also prohibited.

Condensate discharge to be routed to a code approved place of disposal. Discharge of HVAC coil condensate to the exterior is not allowed without written permission from the DEN Mechanical Engineer.

When Code requires a secondary method of condensate drain protection, manufacturer-furnished overflow drains with properly sized condensate traps shall be fully detailed in the contract documents. Pumped condensate and water level detection alternatives are prohibited. Secondary Condensate Drain pans may only be used when a manufacturer overflow is not available.

Wherever units equipped for cooling service are installed above facilities, such as electrical power equipment, computer equipment, data server or telecommunications equipment, or other electrical or electronic equipment susceptible to malfunction if exposed to water, Contractor shall provide a supplemental drain pan to serve as additional protection against leakage, overflow, or other failure of the primary drain pan normally comprising a part of the air conditioning equipment. Supplemental drain pans are to be constructed of 20 gauge (minimum) galvanized steel, with a minimum depth of 2 inches, fabricated, braced, and supported so as to ensure stability. Secondary condensate drain pans shall not interfere with other maintenance and access requirements detailed in this Design Standards Manual.

All overflow drains that are required to terminate with an open site shall have signs with directions on procedures for notification of maintenance control.

8.1.16 Secondary Condensate Drains

When the code requires a secondary condensate drain from HVAC equipment coil drain pans, manufacturer-furnished overflow drains should be used. Secondary drain pans shall only be used when no option exists from the manufacturer.

Secondary drain pans shall be fully design and detailed on the contract documents. No component of the drain pan shall be left to the contractor's discretion. Details shall accommodate the following:

A. Easy removal of the secondary pan for maintenance of equipment.
B. Secondary pans shall be supported independently of HVAC equipment.
C. Structural supports and connections to the building structure.
D. Dedicated piping from the drain pan to an open site location. Open site termination shall include signage defining procedures in the event of a leak. Sign shall read, "If water is observed from the pipe below, immediately contact Maintenance Control at (303) 342-2800".
E. Drain pan shall not block or inhibit access to surrounding systems.

Pumped primary or secondary pans and leak detection alternatives are prohibited.

8.2 Plumbing System Components

8.2.1 General

A. Electric (instantaneous type or small storage tank) domestic water heaters shall be provided at each toilet room. No central domestic hot water system is provided in the Terminal Building Complex or in the Concourses.

B. All potable water piping to Tenant lease areas shall be furnished with a digital water meter on the potable water service entrance to the Tenant lease area. The meter shall be in an accessible area within the Tenant lease area. The meter shall have native BACnet communication and connect directly to the DEN EMCS.

C. Exterior grease traps shall be provided for fixtures in kitchen and food service concessions areas as these facilities may require.

D. All water supply to fixtures shall be protected by an approved vacuum breaker.

E. A detailed area chart/plan shall be prominently displayed in the main equipment rooms showing the locations of all main piping and valves. The Design Consultant is to include this as a Contractor requirement.

All domestic hot and cold water and storm drainage piping within conditioned areas shall be insulated. All piping subjected to freezing temperatures shall be insulated and protected from freezing as appropriate.

8.2.2 Plumbing Fixtures and Equipment

Fixtures and Equipment are to be of the latest design to avoid becoming untimely obsolete.

All lavatory faucets in public and private toilet rooms shall be provided with flow-restricting devices on all outlets. Lavatories faucets shall be specified to flow no more than 0.5 gpm. Provide single-tempered water faucets at lavatories with 102°F supply temperature available within 30 seconds of activation and for a period of not less than 20 seconds. Metering lavatory faucets are to use no more than 0.25 gallons of water per metering cycle.

All lavatories (including physically disabled) can be wall-hung or counter-mounted. Wheelchair access must be provided for handicapped fixtures. A minimum 29" clear knee space is required with a maximum 34" rim height or as defined by the latest version of the ADA.

A. Water closets and urinals shall be a wall-hung, blow-out type. Tank-type/cistern-type water closets shall not be used in the terminal complex. The flush valves and fixtures shall be provided as follows:
   a. 1 GPF water closets
   b. 0.125 GPF urinals
   c. 0.35 GPM lavs
   d. 1.5 GPM kitchen sinks
   e. 1.75 GPM showers

B. To prevent urine salt buildup, urinals shall connect directly downstream of the water closet sanitary sewer main for allowance of future low-flow fixtures. Urinals shall not be headered together and then connected to the sanitary mains.

C. Waterless urinals shall not be allowed for use at any DEN facility.

D. Automatic valves shall be provided for urinals and lavatories in public areas. Valves shall be concealed and provided with infrared sensors for valve actuation. (Coordinate with electrical Design Consultant.) Battery-powered devices shall not be used.

E. Stop valves shall be provided on all fixtures, including water coolers.

F. All fixture types shall be in the design documents and called out on the contract drawings.

G. All urinal and water closets shall have a double cleanout on the sanitary or vent riser prior to connection to the main piping to allow for cleaning of piping to the fixture and from the fixture branch to the main. Double cleanout assembly shall be completely detailed on the contract documents.

H. All water coolers in public areas shall be barrier-free bi-level type and include a bottle fill station on the lower cooler.
I. Roof vents (DWV) shall be of 3-inch diameter minimum.
J. Drains from service and slop sinks shall be a minimum of 3-inch diameter.
K. Minimum potable water line size shall be 3/4-inch except for branch to fixture, which may be 1/2-inch.
L. Provide a floor drain below all non-carpeted interior vestibule areas. (Drain shall be located below steel mat.)
M. Air admittance valves shall not be used unless approved in writing by the DEN Mechanical Engineer. Only continuously piping island fixture vents (aka, foot vents) as described by the IPC shall be used.
N. A minimum of one hose bib shall be located in each mechanical and pump room for general wash down.
O. All traps shall be protected in accordance with the IPC. Trap protection products are allowed but require written permission of the DEN Mechanical Engineer before inclusion into design. Sure Seal and similar products may be provisionally allowed, Trap Guard and similar products are prohibited.
P. Due to availability issues and relative cost, 5-inch piping and valves shall not be used.

8.2.3 Piping

Refer to the specifications for pipe material types. PVC piping with approved smoke/flame spread wrap is to be used for tenant sanitary and grease sewer systems when draining corrosive waste from soda fountains and beverage towers. PVC piping is to extend to the connection point of the building's sewer system. Otherwise, PVC shall not be used inside the building above grade without written permission of the DEN Mechanical Engineer. Cast iron shall not be used for underground piping.

All piping below grade under aprons, roadways, taxiways, building structures, and paved areas shall be encased in flowable backfill. The exception to this is when installed underfloor structures that use a void form as a sacrificial element to create a space between the floor and the heave of expansive soil. In this case, a plumbing void system such as Plumbing Void by VoidForm Pipe Isolation Systems and equivalents shall be used.

All sanitary sewer piping shall slope at no less than ¼" per linear foot (2.08%) for allowance of future low-flow fixtures.

Size of the roof and overflow piping shall be sized based on the flow rate through the roof drain. Minimum slope for roof and overflow drain piping shall be no less than 1/8" per linear foot (1.08%). Size of piping is to remain the same for the entire routing of pipe; pipe size shall not decrease for vertical leaders. If the pipe slope changes from a greater slope to a lesser slope, the entire system shall be sized based on the lesser slope.

Design shall ensure that the minimal pipe length is achieved and that no unnecessary loops or branches are used. Piping shall be routed in the most direct route feasible. No piping shall be routed through/across the AGTS tunnel.

Minimum size of piping is 2" in diameter for sanitary and grease waste and vents.

8.2.4 Plumbing Pumps

All plumbing pumps shall have manual isolation on each side of the pump. An electrical disconnect shall be located within fifteen feet of the pump unless dictated otherwise by Code.

Lift station/well sanitary pumps shall be designed for easy removal from the sump without disconnecting and draining major components of the sanitary system.

All sump pumps shall have controls furnished with a high-level remote alarm and strobe/light. Signage shall be provided and located in a nearby occupied area that indicates alarm response action. For duplex (or greater) pump systems, pump controls shall also include lead/lag alternating operation and on/off settings for each pump. All operational levels shall be fully detailed on the contract documents and not left up to the contractor.

8.2.5 Plumbing Sumps

Plumbing sumps larger than three (3) feet in diameter and two feet deep shall be constructed of cast-in-place or precast concrete. Plastic or FRP sumps shall not be used in below-ground sumps due to the highly expansive nature of DEN soils. All sumps shall be fully detailed and coordinated with structural and civil engineers.

8.2.6 Heat Trace Systems

Electric heat trace is not a preferred method of thermal protection of piping. When heat trace is required and approved in writing by the DEN Mechanical Engineer, the entire system limits shall be detailed on the contract drawings, completely specified in the contract documents, and completely coordinated with other disciplines for electrical load and maintenance access. No portion of system design shall be left to the Contractor.

Plumbing Drawings shall include the following:

A. Location of heat trace control panel and audible/visual alarm
B. Location of alarm signage and detailed requirements of alarm procedures.
C. Limits of piping to be heat traced
D. Control diagram showing interface with DEN EMCS, sequence of operation including all devices, and complete points list.

8.2.6.1 Tenant Use of Heat Trace Systems

No tenant domestic water shall be exposed to freezing temperatures, even with heat trace systems.

8.3 Energy Conservation in Plumbing Systems Design

8.3.1 Domestic Hot Water

Hot water for domestic water use shall be designed in accordance with ASHRAE 90.1-2010 Section 7 and OSHA requirements. ASHRAE 90.1 establishes minimum requirements for hot water generator recovery efficiency, storage tank insulation, pipe insulation, temperature controls, pump operation, equipment automatic shutdown, and conservation of hot water.

8.3.2 Temperature

The domestic hot water system shall be designed for a supply temperature of 122°F for circulated systems and 140°F for storage systems per OSHA requirements. For the public spaces, provide lavatories with 102°F water at each point of use.

The domestic hot water serving five (5) or more fixtures or the furthest fixture is more than 30 feet from the water heater shall have a circulation loop with a temperature-controlled circulation pump. Domestic hot water shall be circulated to maintain a temperature of 122°F.

8.3.3 Safety Devices

Safety devices shall be provided on the hot water generators and storage devices. Safety devices shall be as required by code and, as a minimum, shall include energy cut-off devices, relief valves, and/or temperature or combination temperature and pressure relief valves.

All water heaters, regardless of size, shall have an expansion tank on the domestic cold water inlet.

8.4 Natural Gas

8.4.1 Sizing

Gas piping shall be sized per the requirements of the International Fuel Gas Code, CCD Amendments to the code, and local Gas Utility. Additional criteria:

A. Gas specific gravity: 0.65
B. Gas thermal capacity: 834 BTU per cubic foot

8.4.2 Metering

Metering and pressure regulation for all buildings shall comply with the requirements of Xcel Energy. Contact the DEN PM to coordinate the current requirements.

Natural gas service for concourse Tenants will be connected from the metered area designated by DEN. The Designer shall coordinate gas and meter requirements with the local gas utility.

All gas requirements (demand and pressure) shall be shown on the drawings.

8.4.3 Gas Systems Protection

Architect and Engineer of Record for design of facilities shall design protective measures for all gas piping systems at DEN. All gas piping above grade, both upstream and downstream of meters, shall be protected. Protection and access for all utility equipment shall be coordinated with Xcel Energy.

All gas piping, meters, pressure regulators, appurtenances, and systems shall be fully protected from possible collisions with vehicles, baggage cart tugs, support equipment, etc. To the greatest extent possible, gas systems shall be located away from areas where it is possible for vehicles and/or equipment to strike it directly and/or indirectly through adjacent walls that offer inadequate protection from such vehicle strikes. Standard CMU walls and concrete curbs do not provide adequate protection, as can be seen from the photos below. In addition, gas systems shall be protected from grade level to ceiling, as strikes can occur at nearly all elevations that are not either protected and/or concealed in ceilings.

Gas piping, meters, pressure regulators, appurtenances, and systems exposed to aircraft apron areas shall be fully protected all the way from grade level to the bottom of the soffit level.

Figure 8-1: Concourse B: Tug Damage to Wall

Figure 8-2: Gas Piping Strike: Side and Front Views

8.4.4 Sustainability

As a part of the City and County of Denver's Office of Climate Action, Sustainability, and Resiliency (CASR), the Energize Denver Ordinance, which establishes energy use intensity targets for buildings over 25,000 sq. ft. DEN is working to reduce our carbon emissions impact. As such, no new gas-fired equipment or fixtures, except for kitchen cooking equipment (stoves, ovens, etc.), shall be installed at DEN without written permission from the DEN Mechanical Engineer.

Gas fireplaces are not allowed at DEN.

8.5 Tenant Remodel Requirements

8.5.1 Plumbing Requirements

Tenant plumbing fixtures and piping systems, including all rough-in and final connections, shall be furnished and installed by the Tenant. Plumbing fixtures and accessories shall be of commercial quality and shall use best practices in water conservation. All plumbing systems shall be installed in accordance with the IPC and local plumbing codes. No plastic piping is permitted above the Tenant's ceiling, in a return air plenum, or below a floor. Plastic Piping is only allowed in below-ground applications and as indicated in section 8.2.3 Piping.

Indicate on floor plans the routing and size of beer and soda conduits.

Domestic water shall be sized by fixture units and the curve for flush valves per the DDS. The Tenant shall provide a domestic cold-water branch from the main located in the pump/water service entry room when service is not available in the lease area.

8.5.2 Grease Waste

Food Service Tenants shall connect all grease waste to designated grease waste lines. Flow and capacity diagrams of all existing grease interceptors are available from the DEN Mechanical Engineer but are to be verified in the field for discrepancies in the area of work. Refer to the Standards and Criteria DSM for master diagram requirements. All new flow diagrams shall be developed using the existing diagrams as guidelines. Consultants shall submit any new diagrams to the DEN Mechanical Engineer at the Issue for Construction and Record Documents phases of the project independently of any other required submittal. Submittals are to be in Revit; refer to the Digital and Facilities Design Standards Manual for specific BIM requirements.

8.5.3 Water Heaters

Provide electric water heaters when water heaters are required. Gas-fired water heaters may be used ***only*** with written acceptance of the DEN Mechanical Engineer and verification there is the adequate volume in space for combustion air and an accessible route for the flue. See 8.4.4 Sustainability for reducing carbon emissions at DEN.

All water heaters shall have an expansion tank, regardless of the water heater size.

For increased efficiency, heat-pump water heaters shall be considered.

8.5.4 Water Meters

The Tenant shall furnish and install a digital flow meter on the water service entrance to the Tenant lease area. The meter shall be in an accessible area within the Tenant lease area. The water meter shall have native BACnet communication and connect directly to the DEN EMCS. Provide a lockable isolation valve directly upstream of the meter.

Domestic cold-water service to the Tenant lease area will not need to be metered if Tenant has less than 16 water supply fixture units (wsfu) total for the project. Fixtures shall be sized per the latest version of the International Plumbing Code (IPC).

8.5.5 Backflow Prevention

Backflow prevention is required on all Tenant connections to the building's domestic water main, including service to a single hand sink. The backflow preventer shall be in an accessible area within the Tenant lease area.

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Chapter 9 - Energy Analysis and LEED

9.0 Energy Analysis and LEED

There are many factors unique to the airport terminal and other airport buildings that enter into the design of an energy and water efficient facility. These factors include economic, operational, architectural, passenger experience and environmental quality, mechanical, and electrical considerations-- all of which are interrelated.

DEN terminal, concourses, and other buildings shall include design features that emphasize energy and water conservation. Some of these features have been outlined in earlier chapters but are summarized in this section for emphasis.

Building projects in excess of 5,000 square feet and/or required by DEN Mechanical Engineer shall have a computer energy model (the Energy Analysis) performed to establish baseline and design energy performance according to the methodology established in the most current version of ASHRAE standard 90.1. Energy Analyses shall simulate performance of all relevant building spaces, components, systems, and subsystems and shall produce aggregate building energy performance estimates for both peak demand and consumption of all sources of energy to the designed building (primary and secondary) for a full year, Energy Analyses shall also include economic analyses of energy costs based upon current or expected DEN utility rates and rate structures. Energy cost budgets shall be established and shall meet the requirements of ASHRAE 90.1. This standard allows tradeoffs between mechanical and electrical systems and the building envelope. These tradeoffs shall supersede specific requirements presented after written approval by DEN Mechanical Engineer or Energy Manager.

9.0.1 Codes and Standards

All Designs and Energy Analyses shall meet the requirements detailed in the following:

A. International Building Code
B. International Energy Conservation Code
C. ASHRAE 90.1 (Latest version at time of NTP)

Where the requirements of this chapter or the Codes and Standards themselves deviate from one another, the more stringent of the two shall apply.

9.0.2 LEED Certification

In order to mitigate the negative environmental impacts of the built environment, and to recognize the total cost of capital project ownership, all buildings constructed or renovated at DEN with City funds or funding capacity, and meeting the following criteria, shall be designed and constructed according to the principles outlined in the USGBC’s LEED standards and other applicable design, construction and management leading practices for sustainability. The following criteria apply to projects at DEN:

All building projects over 5,000 square feet shall be certified to LEED-NC Gold certification, with the goal of achieving LEED-NC Platinum certification, under the most currently available rating system applicable for the project type.

Project less than 5,000 square feet are expected to meet the intent of LEED-NC Gold certification, with the goal of meeting the intent of LEED-NC Platinum certification credit thresholds and performance criteria, where feasible.

Projects over 5,000 square feet should also be eligible to achieve ENERGY STAR status after one year of operations. Contact the project PM for additional information.

All existing and future City operated facilities shall incorporate all applicable LEED for Existing Buildings (O&M) leading practices into facility operation and maintenance.

In the rare case that it is determined that certification is not feasible, the Designers shall submit documentation of technical and/or cost infeasibility to the DEN PM, who will seek a policy exemption. If given a formal exemption the project shall use LEED guidelines to achieve the equivalent (to the extent possible) of LEED-NC Gold certification, with the goal of achieving LEED-NC Platinum equivalent certification.

The Consultant shall review the current LEED Rating System and, in coordination with other project Designers, develop design strategies for maximizing the project's energy and water efficiency. Following the LEED Rating System, the Consultant and DEN shall determine whether the Gold or Platinum level of LEED Green Building Certification is achievable for the project. Following this decision, the Consultant shall tailor the design documents to achieve this certification. Contact the project PM for LEED Rating System documentation.

Due to the inherent operational and site-specific characteristics of DEN, some LEED credits are impossible or prohibitive to achieve. Most of the credit limitations are in the Site Selection (SS) and, to a lesser extent, Water Efficiency (WE) categories, but limitations may exist in all categories. Though any path to certification is acceptable, experience suggests that the Designers focus on achieving maximum points in the Energy & Atmosphere (EA), Materials & Resources (MR) and Indoor Environmental Quality (IEQ) categories. Designers should be careful to consider the inherent trade-off required between enhanced energy performance and increased outside air ventilation in the context of an airport environment. The already large code-required ventilation rates for densely populated public spaces generally make substantial increases over ASHRAE 62.1 requirements prohibitive. In addition, the transient nature of occupants in many airport spaces may reduce the theoretical benefit of increased ventilation.

Various credits may have previously been approved by GBCI under the DEN Airport Master Site and LEED Campus effort. Consultants shall reference the current LEED Campus and Master Site registrations as they apply to their projects.

It is important to remember as a guiding principle throughout the design process that DEN is a vital piece of transportation infrastructure. At no point shall the intended operational functionality of any new construction and/or any existing airport operations affected by the Design be compromised.

9.0.3 LEED and On-Site Solar Power Generation

Energy efficiency shall be a primary focus for reducing the total cost of ownership of capital assets constructed and certified to LEED Gold (or greater) thresholds. It is likely however, that to reach the certification levels required, projects will also need to incorporate renewable energy after all feasible steps toward efficiency have been taken. Considering this, the following approach shall be taken to follow DEN's preference of impact and return on investment: focus on energy efficiency first, then consider on-site (on-building) solar PV, then consider off-site (on-campus) solar PV, then consider off-site (off-campus) solar PV, then consider purchased renewable energy certificates and carbon offsets.

The inclusion of on-building solar PV represents the greatest potential for DEN to derive benefit from renewable energy, on both grid-provided consumption and demand reduction. Renewable energy certificates and carbon offsets are the last preference for DEN and will only be considered to help projects reach their certification thresholds on a case-by-case basis. These projects must be approved by the DEN PM or Energy Manager.

When solar PV systems are considered, roof-top panels with 16% efficiency ratings shall be the minimum efficiency allowable. PV systems shall be evaluated for use in a variety of applications, including building-integrated PV, solar canopies, and rooftop PV.

Rooftop PV systems shall use ballasted or roof-bonded racking systems rated to resist uplift pressures at wind speeds of 150 mph. Racking systems that require penetrations of roofing material will be allowed after approval from the DEN PM or Asset Manager.

9.1 Heat Recovery Systems

When airside heat recovery systems are required, indirect air-to-air heat exchangers or full-coil-heat-pipe systems shall be the basis for designs. Due to climate and cross contamination issues, enthalpy wheel systems (aka, heat wheels) shall not be a design consideration unless approved in writing by the DEN Mechanical Engineer in the 30% submittal.

9.2 Existing Facility Design and Analysis Conditions (Historical Reference)

The following sections (9.3-9.10) outline the design and analysis conditions for many existing facilities throughout the airport and are provided for Historical Reference Purposes Only.

All new Designs and Work shall meet the current prescriptive requirements found throughout the DSMs. Designers shall survey all existing conditions prior to design, analysis or modeling and any questions about existing conditions, construction vintage, etc. shall be submitted to the DEN PM or DEN Mechanical Engineer.

9.3 Building Envelope Evaluation (Historical Reference)

The following represents a summary analysis of ASHRAE standard 90A-1980 and 90.1. Applicable excerpts and specific requirements for DEN are included. The Design Consultant shall refer to these ASHRAE standards and the Model Energy Code for a complete review of the design and other issues that may not be addressed in this section. The Design Consultant shall coordinate these requirements with the architect. This section gives the design consultant criteria for completing an energy analysis during the design phase. The values presented are minimums. Actual U values shall be used in calculating building loads.

9.4 U Values (Historical Reference)

9.4.1 Glazing

Window treatment is a major consideration in providing an energy efficient building shell. The glass shall be double glazing, heat absorbing type (some surfaces with reflective coatings). Internal or external shading may be required to reflect solar rays in the summer and permit utilizing the warming rays during the winter. A U value (winter) of 0.50 Btuh/sq.ft.°F, or better shall be used in the glazing design. Maximum shading coefficient values shall be 0.3 for sloped surfaces, and 0.4 for vertical surfaces. Highly reflective glass is not permitted for airport facilities.

9.4.2 Walls

The walls of all facilities shall be well insulated to conserve energy. A U value of 0.10 Btuh/sq.ft.°F, or better shall be used in the design. The architect shall design the ratio of glass-to-wall according to Table 9-1: Heating and Cooling Criteria. If the architect wishes to incorporate more glass, the U value of the opaque wall and/or the glass must be decreased accordingly to meet the U_o requirements as outlined in Table 9-1: Heating and Cooling Criteria.

Any building that is mechanically cooled shall have an Overall Thermal Transfer Value (OTTV) for the gross area of exterior walls above grade not exceeding 33.2 Btuh/sq.ft.

9.4.3 Roof

The roof of the facility shall be well insulated to conserve energy. A U value of 0.05 Btuh/sq.ft.°F, or better shall be used in the design. If the design incorporates skylights, the architect shall remain in compliance with the U_o requirements by adhering to the allowable combinations of glass vs. opaque roof.

Any building that is heated shall have a combined thermal transmittance value (U_o) for roof/ceilings not exceeding 0.074 Btuh/sq.ft.°F.

Any building that is mechanically cooled shall have a combined thermal transmittance value (U_o) for roof/ceilings not to exceed 0.074 Btuh/sq.ft.°F and shall have an Overall Thermal Transfer Value (OTTV) for the gross area of a roof assembly not exceeding 8.5 Btuh/sq.ft.

Any building that is mechanically heated shall have a combined thermal transmittance value (U_o) for the gross area of exterior walls not exceeding 0.32 Btuh/sq.ft.°F for buildings over three stories in height; 0.265 Btuh/sq.ft.°F for 3 stories and under.

9.4.4 Floors Over Unheated Spaces

For floors of heated spaces over unheated areas, the U_o value shall not exceed 0.05 Btuh/sq.ft.°F. For floors over outdoor air (i.e., overhangs) the U_o value for heating shall meet the same requirements as for roofs, 0.074 Btuh/sq.ft.°F.

Any building that is mechanically cooled shall have a combined U_o for floors exposed to the outdoors air not to exceed that which would be determined by the heating criteria.

9.4.5 Slab-on-Grade Floors

For slab-on grade floors, the thermal resistance of the insulation around the perimeter of the floor shall be R = 7.3 sq.ft.F/Btuh for heated slabs and R = 5.15 sq.ft.F/Btuh for unheated slabs. The insulation shall extend downward from the top of the slab for a minimum distance of 24 inches or downward to the bottom of the slab then horizontally beneath the slab for a minimum total distance of 24 inches.

9.4.6 Alternatives

ASHRAE standards do allow that the U_o or OTTV value for a component of the building envelope (such as the roof or the walls) can be increased above the code required value, if the U_o or OTTV values for the other components are decreased below the code required value, such that the total overall building combination U_o is still in compliance with the code. Refer to the ASHRAE 90.1 for applicable formulas for determining acceptable combinations of thermal transmittance areas.

A building designed to be both heated and/or cooled shall meet the more stringent of the heating or cooling requirements of the exterior envelope when requirements differ.

9.4.7 Summary

The evaluation of the building shell requirements for DEN in accordance with ASHRAE standards are summarized in the following table. This table indicates the allowable thermal values for walls and roofs (based upon 6283 annual heating degree days and a northern latitude of 39° for Denver, Colorado).

Table 9-1: Heating and Cooling Criteria

Building Element	Building Height	Seasonal Mode	Maximum Allowable Value
Walls	More than 3 stories	Heating	U_o = 0.320 Btuh/sq.ft.°F
Walls	3 stories or less	Heating	U_o = 0.265 Btuh/sq.ft.°F
Roof & Ceiling		Heating	U_o = 0.074 Btuh/sq.ft.F
Floors - over unheated areas		Heating	U_o = 0.050 Btuh/sq.ft.°F
Floors - over outdoor air		Heating	U_o = 0.074 Btuh/sq.ft.°F
Walls		Cooling	OTTV= 33.2 Btuh/sq.ft.°F
Roof &Ceiling		Cooling	U_o = 0.074 Btuh/sq.ft.°F
Roof & Ceiling		Cooling	OTTV= 8.5 Btuh/sq.ft.°F
Floors - over unconditioned areas		Cooling	U_o = 0.080 Btuh/sq.ft.F
Floors - over outdoor air		Cooling	U_o = 0.074 Btuh/sq.ft.°F

9.5 Building Components (Historical Reference)

9.5.1 Daylighting

The fenestrations shall provide natural light (daylighting) to reduce the electrical energy requirements during daytime hours. Automatic photo sensing controls can reduce artificial light levels when daylight is available through skylights and windows. An appropriate balance between skylight and lighting effects shall be made with the requirement of overall thermal efficiency. ASHRAE 90.1 provides a means to evaluate alternatives and trade-offs between daylighting and other energy conserving features. This shall be coordinated with the electrical design consultant.

9.5.2 Entrances

Building entrances require special consideration in airport facilities. A high volume of traffic is experienced at personnel entrances, baggage handling, and service entrances. A high volume of air transfer also can occur at these locations. There are several reasons for this:

A. The building pressurization due to exhaust requirements.
B. Air pressure on doors and door openings from winds.
C. Stack effect due to building height.

To design for the alleviation of these problems the Design Consultant shall:

A. Provide sufficient outside air through the air handling systems to properly pressurize the facility.
B. Provide windbreaks and vestibules at the door entrances to protect direct blasts of wind from entering the building, including door heaters for winter conditions.

Vestibules in airport facilities are less effective than they might be in other applications, due to the high volume of traffic, and percentage of time both doors will be open during busy periods. However, properly sized vestibules will significantly reduce energy consumption in airport facilities during non-peak airport use.

9.5.3 High-Bay Areas

High-bay ceiling areas shall be utilized to an energy advantage. It is proposed that supply air distribution be designed to permit stratification in the high-bay areas during the summer. The summer return air shall be drawn from the floor level. During winter months, return air shall be pulled from near the ceiling, as high as possible, capturing stratified hot air and heat dissipated by lights and people. Vertical return air shafts with automatic motorized dampers incorporated into the control scheme shall provide this energy management feature.

9.6 Air Leakage - All Buildings (Historical Reference)

9.6.1 Windows

Windows shall be designed to limit air leakage; the air infiltration rate shall not exceed 0.34 CFM per foot of operable sash crack on exterior openings. Coordinate this requirement with the architect.

9.6.2 Swinging, Revolving or Sliding Doors for Nonresidential Use

Where these types of doors are used, they shall be designed to limit air leakage; the air infiltration rate shall not exceed 11 CFM per linear foot of door crack.

9.7 HVAC Systems (Historical Reference)

9.7.1 Controls and Automation

Refer to the Controls and AHU Controls sections for each facility later in this standard.

9.7.2 Variable Water Volume (VWV) Pumping

Variable water volume pumping systems are based upon proper location of pressure transmitters (near the end of the piping loop) and variable speed pumps or staged pumps to provide only the system flow and pressures required to serve the actual cooling or heating load at a particular time. Variable water volume piping shall be employed to reduce energy consumption of hot and chilled water systems. Final design may include additional applications that could be designed with VWV pumping to advantage in reducing energy usage. This determination is left to the discretion of the Design Consultant (i.e., the condenser water systems).

9.7.3 Simultaneous Heating and Cooling

The use of both heating and cooling simultaneously to achieve comfort conditions within a space will not be permitted. The Design Consultant shall review ASHRAE standard 90.1 for exceptions, if necessary.

9.7.4 Outdoor Air Reset

As of 2014, hot and chilled water supply temperatures are no longer reset in relation to outdoor air temperature to save energy during other than design conditions. Hydronic system temperatures are allowed to drift at the CUP level as demand and energy savings analytics dictate.

9.7.5 Energy Recovery (Historical Reference)

It is recommended that consideration be given to the use of recovery systems that will conserve energy (provided the amount expended is less than the amount recovered) when the energy transfer potential and the operating hours are considered. Outside air supply ducts should be located near exhaust ducts wherever possible to increase the economics of heat recovery.

9.8 HVAC Equipment (Historical Reference)

9.8.1 Equipment Efficiency

Primary criteria for the selection of major heating and cooling plant equipment shall be its efficiency of operation. Equipment shall be selected that exceeds the requirements of ASHRAE standard 90.1.

9.8.2 Minimum Coefficient of Performance/Efficiency Levels

Minimum Coefficient of Performance (COP) and/or efficiency levels are established for HVAC system Equipment and HVAC System Components. It is intended that no lower values than those established in this Standard will be acceptable. It is further intended that where equipment of higher COP/Efficiency capability is known to be available on the open market, it will be the system Design Consultant's option to specify such higher efficiencies as he deems to be suitable.

Table 9-2: Commercial/Industrial Furnaces and Boilers

Types of Equipment	Percent*
Forced-air furnaces and low-pressure steam or hot-water boilers	80
All other vented heating equipment	80

**Combustion efficiency of commercial/industrial furnaces and boilers is defined as 100% minus stack losses in percent of heat input. Stack losses are:*
•Loss due to sensible heat in dry flue gas
•Loss due to incomplete combustion

•Loss due to sensible and latent heat in moisture formed by combustion of hydrogen in the fuel

Table 9-3: Electrically Driven HVAC System Equipment

Standard Rating Capacity*	EER*	COP**
Under 65,000 Btuh (19,050 W)	7.8	2.28
65,000 Btuh (19,050 W) and over	8.2	2.40

**Refer to ASHRAE 90A for standard ratings*
***The Department of Energy has established required test procedures for single phase air-cooled residential central air conditioners under 19 kW (65,000 Btuh) in capacity, which have been incorporated in ARI Standard 210-79. EER and COP values in this table are based on Test A of the DOE Test Procedures.*

9.9 Insulation (Historical Reference)

9.9.1 Air-Handling Duct System Insulation

The Design Consultant shall insulate ducts, plenums, and enclosures as required by ASHRAE standard 90.1.

9.9.2 Piping Insulation

Piping installed to service buildings and within buildings shall be thermally insulated in accordance with ASHRAE standard 90.1.

In general, piping insulation shall be fiberglass in interior installations. Insulation shall be provided with an all service jacket. Piping systems carrying fluids that will be below the ambient dew point temperature at any time shall have a vapor barrier.

9.10 Plumbing Systems (Historical Reference)

9.10.1 General

Where possible, the Consultant shall investigate systems to reduce water consumption and waste discharge. The use and availability of ultra-low flow (16 oz. or less) flush valves and powerless infrared faucets shall be investigated. These systems shall be reviewed and accepted in writing by the DEN Mechanical Engineer.

End of Chapter

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Chapter 10 - Gate Services

10.0 General Requirements

This chapter outlines specific requirements to be included in the overall mechanical system designs and specifications for issuance of construction documents suitable for bidding and permitting. These designs and specifications shall include PCA systems where applicable for specific locations. This chapter describes the general mechanical gate services and includes PCA system and potable water cabinet design requirements and criteria for specific locations and the scope of participation that is required by Design Professionals of record.

DEN has a mixture of PCA systems. Systems are designated and limited by building:

10.0.1 Acronyms and Definitions

Table 10-1: Gate Services Acronyms and Definitions

Term	Definition
Fixed walkway	Enclosed, fixed connector extending from an airport concourse gate to a loading bridge, enabling passengers, aircraft/concourse access without direct exposure to the elements
GPU	Ground Power Unit
Jet Bridge, Jetway, or Loading Bridge	Enclosed, movable connector that extends from an airport concourse gate or fixed walkway to an aircraft, enabling passengers, aircraft/concourse access without direct exposure to the elements
PCA	Pre-Conditioned Air
PWC	Potable Water Cabinet

10.0.2 Concourse A

Consists of a two-pipe changeover hydronic system with PCA plant located in southeast basement level of the central core. Due to limitations of clearance on the south side of the building, thus limiting aircraft parking and size, all PCA units are 45 ton. PCA units on the north side were sized based on their gate diversity as of 2006. Several stand-alone DX PCA units serve individual add-on gates. This practice has been discontinued.

10.0.3 Concourse B

Consists of unitary DX PCA units serving each gate. The concourse has a mixture of gate-mounted units and stand mounted units. Stand mounted units are generally used at congested dual-bridge international gates where bridge-mounted units would block access to bridge-mounted electrical equipment. The majority of PCA units are sized based on the original gate aircraft mix in 1994. In 2008, the south commuter finger was added, and new DX PCA units were added for commuter gates on that facility. In 2013, the PCA units at gates 32, 36, 38, 39 and 42 were replaced with larger DX units to accommodate the arrival of the 787.

10.0.4 Concourse C

Consists of a two-pipe changeover hydronic system with PCA plant located in southeast basement level of the central core. In 2006, all PCA units were replaced with 60-ton units. Several stand-alone 60-ton DX PCA units serve individual add-on gates. This practice has been discontinued.

10.0.5 Plant Description

The existing PCA plants on Concourses A and C are secondary two-pipe changeover utility plants that connect to the CUP to provide an isolated thermal distribution system to the gate PCA units. In general, the PCA plant consists of chillers, heat exchangers, pumps, and future space for thermal energy storage units.

All new PCA Plants shall be four pipe systems.

10.0.6 Plant Design

All PCA plants shall be designed for a full gate expansion; approximately 50 gates at Concourses A, B, and C. All plant equipment furnished shall be selected to handle a minimum of half of the full total build-out load. The following criteria shall be used for selection of PCA plant equipment:

10.0.6.1 Chiller Selection

A. Chilled glycol mode: 20°F CWS, 40°F CWR (20°F design ΔT)- 30% ethylene glycol
B. Heating glycol mode: 180°F HWS, 140°F HWR (40°F design ΔT)- 30% ethylene glycol

10.0.6.2 CUP Connection Criteria

A. Chilled water condenser water 56°F CHR in, 66°F CHR out (10°F design ΔT). Note that plant equipment should be capable of operating at CHR temperatures as low as 50°F or contain mixing valves for proper equipment operation.
B. Heating water 220°F, 170°F (50°F design ΔT)

The design of plant equipment shall accommodate component selections to provide partial system operations in the event of failure of any single component. Multiple units of each system component (50% capacity each minimum) are required. Plant designs shall not have less than two units in each system type.

Due to the use of Ethylene glycol in the system, floor drains will not be permitted within the PCA plant rooms. If equipment drains are required, provide hub/funnel drains at an elevation above the curb elevation of the room and connect it to existing drain piping.

10.0.7 PCA Hydronic Design

PCA hydronic piping shall be sized for ultimate build-out of the facility unless directed otherwise by the DEN Mechanical Engineer.

Due to large changes in aircraft mechanical conditioning loads from the original gate design of 1994, many existing PCA hydronic mains do not have capacity for ultimate concourse build-out.

Pumps shall be selected for maximum operating efficiency, (i.e., slightly to the right of maximum efficiency point on the pump curve). Multiple pumps for parallel operation shall have relatively steep performance curves. All pumps shall be specified for VFD operation. Standby pumps and accessories shall be provided for both heating and cooling systems. Pumps shall be arranged in a parallel configuration and headered to maximize pumping flexibility. New pumps shall be sized for half of design flowrate.

Pump design flowrates and selected system diversities shall be determined on a project basis and coordinated directly with the DEN Mechanical Engineer. Existing systems have diversities ranging from 15%-40% depending on Airline usage.

All PCA hydronic systems use 30% ethylene glycol.

Shut-off valves shall be provided at every branch take-off from the PCA hydronic main, upstream, and downstream of every expansion compensation device.

All new piping designs shall include expansion compensation, anchoring, guiding, and branch take-offs to each gate position.

Older gates at DEN use STUs (Service Transport Units) to support flexible hydronic piping and electrical cabling between the fixed building connections and PCA and GPU units mounted underneath passenger loading bridges. Whenever passenger loading bridges are replaced, the STUs are also replaced with pantographs. Designers shall coordinate with passenger loading bridge manufacturers to ensure that replaced flexible hydronic piping fits inside pantographs.

No flexible hydronic piping shall be used in the PCA glycol hydronic system, except to connect rigid hydronic piping at building to PCA units mounted underneath passenger loading bridges.

10.0.8 Equipment Support

All equipment located in the PCA Plant room shall be isolated from the basement floor and shall be installed on independently supported pads with caissons. If deemed cost effective, entire room floor may be supported separately from concourse basement flooring. No slab on grade systems shall be used for equipment or equipment supports.

10.1 PCA Units

10.1.1 PCA Unit Sizing

All gates shall have a PCA unit, unless otherwise directed by the DEN PM. All PCA units shall connect to the concourse PCA Plant when available.

PCA selection shall be made based on the potential largest and smallest aircraft the gate can handle; e.g. the PCA unit at the gate shall be able to service both the largest and smallest aircraft the gate is planned on servicing. This restriction typically forces unit sizing to 60 tons. Due to the International Bridge restricting aircraft size on the south side of Concourse A, all PCA units on the south side of this concourse shall be 45 tons.

Table 10-2: Sizing of Aircraft Specific to DEN contains general sizing for aircraft specific to DEN. Sizing may differ for single aircraft based on the number of loading bridges available at the gate. Units shall be specified for a minimum leaving air temperature, as required, for a maximum air temperature of 32 ± 2°F for wide body or jumbo, 35 ± 2°F for narrow body. Contact the DEN Mechanical Engineer to discuss sizing and limitations for each project.

NOTE: Sizing for Airline expectations of 15-minute cool time from hot aircraft to conditioned is not possible with many (or any) units and aircraft configurations. Design Consultant shall document calculated load profiles for all proposed gate configurations in Project Design Analysis Report (DAR).

Table 10-2: Sizing of Aircraft Specific to DEN

Air Carrier	Code	Type	Abbreviation	Single Bridge PCA1	Dual Bridge PCA2
Aero Mexico	(AM)	B737-700 B737-800	B737 B738	45 45	n/a n/a
Air Canada	(AC)	Embraer EMB-175 Embraer EMB-190 A319-100 A320-200	E175 E190 A319 A320	20 20 45 45	n/a n/a n/a n/a

Table 10-2: Sizing of Aircraft Specific to DEN (Continued)

Air Carrier	Code	Type	Abbreviation	Single Bridge PCA1	Dual Bridge PCA2
Alaska Airlines	(AS)	CRJ-700 Embraer EMB-175 B737-400 B737-700 B737-800 B737-900 A320-200	CRJ-700 E175 B734 B737 B738 B739 A320	20 20 45 45 45 45 45	n/a n/a n/a n/a n/a n/a n/a
Allegiant	(G4)	A320-200 MD-80	A320 MD-80	45 45	n/a n/a
American Airlines	(AA)	A319-100 A320-200 A321-200 B737-800 CRJ-200 CRJ-700 CRJ-900 Embraer EMB-170 Embraer EMB-175 Embraer EMB-190 Embraer ERJ-145 MD-80	A319 A320 A320 B738 CRJ-200 CRJ-700 CRJ-900 E170 E175 3190 E145 MD80	45 45 45 45 20 20 20 20 20 20 20 45	n/a n/a n/a n/a n/a n/a n/a n/a n/a n/a n/a n/a
Boutique Air	(BTQ)	PC-12 King Air 350	PC12 K350	n/a n/a	n/a n/a
British Airways	(BA)	B777-200 B777-300 B747-400	B772 B773 B744	60 60 90	n/a n/a 60
California Pacific	(DYN)	Embraer ERJ-145	E145	20	n/a
Copa Airlines	(CM)	B737-800	B738	45	n/a

Table 10-2: Sizing of Aircraft Specific to DEN (Continued)

Air Carrier	Code	Type	Abbreviation	Single Bridge PCA1	Dual Bridge PCA2
Delta Air Lines	(DL)	MD-88 MD-90 A319-100 A320-200 A321-200 A330-300 A350-900 Embraer EMB-170 Embraer EMB-175 Embraer EMB-190 CRJ-200 CRJ-700 CRJ-900 B717-200 B737-700 B737-800 B737-900 B757-200 B757-300 B767-300 B767-400 B777-200	MD-88 MD-90 A319 A320 A321 A333 A359 E170 E175 E190 CRJ-200 CRJ-700 CRJ-900 B717 B737 B738 B739 B752 B753 B763 B764 B772	60 60 45 45 45 60 60 20 20 20 20 20 20 45 45 45 45 45 45 60 60 60	n/a n/a n/a n/a n/a n/a n/a n/a n/a n/a n/a n/a n/a n/a n/a n/a n/a n/a n/a n/a n/a n/a
Denver Air Connection	(DAC)	D-328	D328	20	n/a
Edelweiss	(WK)	A330-300	A333	60	n/a
Frontier Airlines	(F9)	A319-100 A320-200 A321-200	A319 A320 A320	45 45 45	n/a n/a n/a
Icelandair	(F1)	B757-200W	B752W	45	n/a
JetBlue Airways	(B6)	A320-200	A320	45	n/a
Lufthansa	(LH)	B747-400 A330-300 A340-600 A350-900 A380-800	B744 A333 A346 A359 A380	90 60 60 60 90	60 n/a n/a
Norwegian	(DY)	B787-800 B787-900	B788 B789	n/a n/a	90/60 90/60
Southwest Airlines	(WN)	B737-700 B737-800	B737W B738W	60T 60T	n/a n/a
Spirit Airlines	(NK)	A319 A320-200 A321-200	A319 A320 A321	45 45 45	n/a n/a n/a

Table 10-2: Sizing of Aircraft Specific to DEN (Continued)

Air Carrier	Code	Type	Abbreviation	Single Bridge PCA1	Dual Bridge PCA2
Sun Country	(SY)	B737-700 B737-800	B737 B738	45 45	n/a n/a
United Airlines	(UA)	A319-100 A320-200 B737-700 B737-800 B737-900 B757-200 B757-300 B767-200 B767-300 B767-400 B777-200 B787-8 B787-9 B787-10 CRJ-200 CRJ-700 CRJ-900 Embraer ERJ-145 Embraer EMB-170 Embraer EMB-175	A319 A320 B737 B738 B739 B752 B753 B762 B763 B764 B772 B787 B789 B7810 CRJ-200 CRJ-700 CRJ-900 E145 E170 E175	45 45 45 45 45 60* 60* 60 60 60 60 n/a n/a n/a 20 20 20 20 20 20	n/a n/a n/a n/a n/a n/a n/a n/a n/a n/a n/a 90/60 90/60 90/60 n/a n/a n/a n/a n/a n/a
Volaris	(Y4)	A319-100 A320-200 A321-200	A319 A320 A321	60 60 60	n/a n/a n/a
WestJet	(WS)	B737-500 B737-700 B737-800	B735 B737 B737	45 45 45	n/a n/a n/a

1- PCA unit to be used when aircraft is only served by a single loading bridge.
2 - PCA unit to be used at each loading bridge when aircraft is only served by two loading bridges.
3 - Aircraft is available with an option for two PCA connections and may vary from airline to airline Requirements coordinated on a gate by gate basis.
**UAL desired for size for DX.*

10.1.2 United Airlines PCA Hose Adapters/Connectors

United Airlines (UAL) uses different PCA Hose Adapters/Connectors than all other airlines. When installing PCA units on Gates primarily used by United Airlines, the Consultant shall coordinate with United Airlines representatives to ensure the correct PCA Hose Adapter/Connector is specified.

10.1.3 Hydronic PCA Units

Hydronic PCA units shall be used when a PCA plant exists in the building of connection. When replacement units are installed that are of larger capacity than the original, a hydronic and load analysis shall be performed by the Engineer to verify piping, pumping and chiller capacity. Design calculations and report shall be submitted to the DEN Mechanical Engineer. Hydronic PCA units shall be furnished with factory-installed reheat coils (typically 18 kW for 60 Ton PC Air units). Verify required reheat capacity with DEN Mechanical Engineer.

Hydronic PC Air units are served by dedicated 2-pipe, hydraulically isolated hydronic systems that are switched over from heating water to chilled water depending on conditions and loading needs. These hydronic systems contain 30% ethylene glycol for freeze protection and low temperature operation required by the PC Air units.

10.1.4 DX PCA Units

DX units shall only be used on Concourse B and select locations where connection to the existing hydronic system is not allowed. DX units shall only be used with written permission from the DEN Mechanical Engineer.

10.1.5 Condensate Drains

Coil condensate drains can drain directly to the apron. Properly sized condensate traps are required and shall be fully detailed in the contract documents. Trap sizing by the contractor is prohibited.

10.2 General PCA Unit Requirements

10.2.1 PCA Unit Supports

PCA units shall be supported on the underside of the loading bridge as close to the cab drive as possible without impeding PCA hose distribution. Locations of PCA units shall not block access to loading bridge electrical j-boxes or access doors. Location of the PCA units shall also take into consideration the minimum bridge level to avoid damage to the unit by crushing or collision with vehicle access below. Minimum bridge position shall allow for a minimum of 12” clear between the bottom of the PCA and the apron to allow for snow.

Stand-mounted PCA units are allowed in limited applications but are not preferred. Stand design shall be performed by the Engineer and completely detailed on the plans. Manufacturer supplied stands shall not be used. Stand design shall include bollard or jersey-type barrier placement maintaining required access for maintenance to PCA Unit and any other equipment within the protected area. Stand and protection shall not interfere with aircraft gate services or concourse vehicle service roads (VSRs). Provide hail protection on DX unit condenser sections.

10.2.2 PCA Controls

All PCA units shall connect to the concourse Facilities EMCS through wireless communications. Stand-alone controls are not allowed.

10.2.3 Accessories

Unless gate parking arrangement dictates otherwise, PCA hose reels shall not be used. All gate side PCA hose shall be stored in PCA hose trolleys. Hose trolleys shall be connected directly to the apron drive of the loading bridge. Single height, single hinge trolleys shall be used for all domestic gates. Dual height or width trolleys may be required at international gates and will require direct coordination with DEN Mechanical Engineer and a gate Airline representative. Hose trolley layout and movement arcs shall be fully coordinated at each gate for all aircraft service equipment and other GSE. Due to the diversity in different airline gate operations, each gate movement shall be detailed. General details that are not airline gate specific are not allowed.

All supply and return piping at the Loading Bridges serving the PCA units shall be flexible and supported in a single or double hinge pantograph depending on the jet bridge length. In general, single hinge pantographs shall be used at two-tunnel jet bridges and double hinge pantographs at three tunnel jet bridges. Shutoff valves shall be installed at the transition from steel piping to flexible piping in the pantograph.

When PCA units are remote stand mounted, metal telescoping ductwork is required on the loading bridge. Rigid metal ductwork and fittings shall be used for the longest extent possible to connect the PCA unit to the telescoping duct. Flexible hose shall only be used in area of movement at the loading bridge rotunda column and connection to the hose system in the hose trolley.

10.2.4 Painting

All PCA units, pantographs, piping, and conduit shall be painted to match the color for the fixed walkway and loading bridge. All structures for stand mounted equipment and safety bollards shall be painted safety yellow. Telescoping ducts and Potable water cabinets shall not be painted and be of a non-reflective finish.

10.3 Fixed Walkways and Passenger Loading Bridges

10.3.1 Ventilation and Conditioning

Fixed walkways and passenger loading bridges have specific pressurization requirements defined in NFPA 415 and additional requirements defined in the Denver Amendments to the ICC series. Denver Community Planning and Development (CPD) still has not finalized requirements for Passenger Loading Bridge (PLB) pressurization compliance.

In the existing Concourses, DEN uses transfer air from the Concourses to pressurize passenger loading bridges.

Previously, DEN has used VAVs to pressurize passenger loading bridges with fixed walkways longer than 20 feet. However, this method of pressurization is no longer required. This method still remains installed on some Gates and is beneficial for passenger comfort during aircraft boarding and deplaning.

DEN recommends installing a VAV to provide conditioned air to fixed walkways and PLBs purely for the comfort of passengers and crew boarding or deplaning aircraft. In the event the existing base building AHUs does not have capacity for an additional dedicated VAV for a new/modified gate, an existing perimeter VAV may be used with written permission of the DEN Mechanical Engineer. In this instance only, dampers shall be installed in the ductwork to isolate operation between the perimeter zone and fixed walkway. The VAV and dampers shall be interlocked with the fixed walkway door. In normal operation, the damper to the fixed walkway will be closed and the damper to the perimeter system will be open. Whenever the walkway door is opened and for a period of five (5) minutes after door is closed the damper to the fixed walkway will be open and the damper to the perimeter system will be closed and the VAV will operate at 100% design airflow.

In new concourse hold rooms or new concourses, the designer shall meet with the DEN Mechanical Engineer to establish design criteria.

10.3.2 PLB Pressure Monitoring

Denver Community Planning and Development (CPD) have specific requirements for pressure monitoring for all new PLBs and modifications to PLBs. All PLBs must monitor and trend differential pressure across the interior PLB door (the door between the Concourse and the PLB), along with the door position status. Differential pressure must be trended at least every 10 seconds when the door is closed, and at least every two minutes when the door is opened. The door switch status must be trended on Change of Status. Per requirements in Chapter 5- Controls, differential pressure and door status trends must be stored in an SQL database accessible to DEN staff.

10.3.3 Fire Protection

Fixed walkways in excess of 20 feet in length have specific fire sprinkler requirements defined in NFPA 415 and additional requirements defined in the Denver Amendments to the ICC series.

10.4 Potable Water Cabinets

10.4.1 Locations

Potable water cabinets (PWC) shall be installed at every gate that contains a loading bridge and any other location as dictated by DEN Planning and/or the DEN Mechanical Engineer. The PWC shall be oriented to face as direct as possible the most common aircraft to be parked at the gate. Location and orientation shall minimize hose length and potential for damage due to abrasion or ground crew operations.

10.4.2 Services

PWC shall connect to the concourse domestic water and sanitary sewer systems. Sanitary vents may extend and terminate above the loading bridge rotunda. Pumped sewer systems should not be a design consideration.

10.5 Update of Standard Diagrams

10.5.1 Flow Diagrams

DEN currently maintains PCA system hydronic flow diagrams for Concourses A and C, which shall be used on any project that modifies the PCA system in these facilities. These diagrams are available from the DEN Mechanical Engineer but are to be verified in the field for discrepancies in the area of work. Consultants shall submit any modifications to these diagrams to the DEN Mechanical Engineer at the Issue for Construction and Record Documents phases of the project independently of any other required submittal.

All new flow diagrams shall be developed using the existing diagrams as guidelines. Consultants shall submit any new diagrams to the DEN Mechanical Engineer at the Issue for Construction and Record Documents phases of the project independently of any other required submittal. Submittals are to be in Revit; refer to the Digital and Facilities Design Standards Manual for specific BIM requirements.

End of Chapter

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Chapter 11 - Facility Design

11.0 Facility Design

This chapter is to be used by the Engineer for a basis of design unless directed otherwise by the DEN Mechanical Engineer. This section contains information on the original basis of design for existing facilities that may no longer comply with current adopted codes. **Most of this section is for historical reference.** The Engineer shall review the requirements below and notify the DEN PM in writing if current codes conflict with the recommendations below and provided recommendations for modifications during the design submittal process.

11.1 Passenger Terminal - Ticketing Level

11.1.1 Design Conditions

A. Summer: 75°F (50% RH Max) No Humidity Control

B. Winter: 70°F No Humidity Control

11.1.2 Air Handling Systems

This area shall be air-conditioned with a VAV system. Refer to 3.0.1 Air Handling Systems for air handling system requirements.

The supply air ductwork system shall consist of medium-pressure ductwork with variable-volume terminal boxes. Each VAV box shall have its own space temperature sensor controls tied to Facilities EMCS. The system shall be sized to supply approximately 1.25 CFM per square foot at maximum flow. Return air shall be through plenum spaces where possible.

11.1.3 Perimeter Systems

The glass wall in the area shall be conditioned by a forced air perimeter system. This system shall be variable volume, heating, and cooling. This system shall not use fan-powered VAV terminal units for heating and cooling.

11.1.4 Air Curtains

Air curtains shall be provided for use on all main terminal entrances. Overhead fan-coil systems shall be used at each entrance with ceiling supply and low return in the vestibule area.

11.1.5 Outdoor Air Requirements

Outside air shall be brought in through the AHU. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.1.6 Ventilation Rates

All new design for proper ventilation shall be in accordance with the recommendations of the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. These values shall be based on terminal peak load occupancy.

11.1.7 Filtration

Outside air shall be filtered with, as a minimum, the use of 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13 and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

11.1.8 AHU Controls

Refer to 5.2 Sample Control Components and Requirements for AHU and HVAC system control requirements.

11.1.9 Central Utility Plant

Chilled water and hot water shall be supplied from the CUP. Secondary pumping shall not be used for these facilities.

11.1.10 Plumbing Requirements

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code.

Plumbing design shall consider the impact of future terminal expansion.

Provide plumbing fixtures for the physically disabled.

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters and basis of occupancy.

11.1.11 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of the National Fire Protection Agency (NFPA) Standards and the building code of the CCD. The following description of fire protection requirements is based on NFPA and FM Global, the current agency insurance underwriter.

A. Provide wet-pipe and dry-pipe sprinkler systems for this area.
B. Provide Class I standpipe system.
C. Provide an extinguisher at each station in the enclosed areas.
D. Provide manual pull-type fire alarm stations at exits.
E. All escalator and stair opening perimeters shall be provided with closely spaced sprinkler heads providing a water curtain.

11.1.12 Smoke Control

All public and Tenant areas shall be served by a separate smoke control system. Refer to the Life Safety DSM for requirements.

11.2 Passenger Terminal - Baggage Claim

11.2.1 Indoor Design Conditions

A. Summer: 75°F (50% RH Max) No Humidity Control
B. Winter: 70°F No Humidity Control

11.2.2 Air Handling Systems

This area shall be air-conditioned with a VAV system. Refer to 3.0.1 Air Handling Systems.

The supply air ductwork system shall consist of medium-pressure ductwork with variable-volume terminal boxes. Each VAV box shall have its own space temperature sensor controls tied to Facilities EMCS. The system shall be sized to supply approximately 1.25 CFM per square foot at maximum flow. Return air shall be through plenum spaces where possible.

11.2.3 Perimeter Systems

The glass wall in the area shall be conditioned by a forced air perimeter system. This system shall be variable volume, heating, and cooling. This system shall not use fan-powered VAV terminal units for heating and cooling except for the existing International.

11.2.4 Air Curtains

Air curtains shall be provided for use on all main terminal entrances. Overhead fan-coil units shall be used at each entrance with ceiling supply and low return in the vestibule area.

11.2.5 Outdoor Air Requirements

Outside air shall be brought in through the AHU. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.2.6 Ventilation Rates

All new design for proper ventilation shall be in accordance with the recommendations of the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. These values shall be based on terminal peak load occupancy.

11.2.7 Filtration

Outside air shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13, and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

11.2.8 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.2.9 Central Utility Plant

Chilled water and hot water shall be supplied from the CUP. Secondary pumping shall not be used for these facilities.

11.2.10 Plumbing Requirements

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code.

Plumbing design shall consider the impact of future terminal expansion.

Provide plumbing fixtures for the physically disabled.

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters and basis of occupancy.

11.2.11 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of the National Fire Protection Agency (NFPA) Standards and the building code of the CCD. The following description of fire protection requirements is based on NFPA and FM Global, the current agency insurance underwriter.

A. Provide wet-pipe and dry-pipe sprinkler systems for this area.
B. Provide Class I standpipe system.
C. Provide an extinguisher at each station in the enclosed areas.
D. Provide manual pull-type fire alarm stations at exits.
E. All escalator and stair opening perimeters shall be provided with closely spaced sprinkler heads providing a water curtain.

11.2.12 Smoke Control

All public and Tenant areas shall be served by a separate smoke control system. Refer to the Life Safety DSM for requirements.

11.3 Passenger Terminal - Atrium

11.3.1 Indoor Design Conditions

A. Summer: 75°F (No Humidity Control)
B. Winter: 70°F (No Humidity Control)

11.3.2 Air Handling Systems

Return air shall be from the occupied space.

11.3.2.1 Occupied Space

This area shall be air-conditioned with a VAV system. Refer to 3.0.1 Air Handling Systems. The supply air ductwork system shall consist of medium-pressure ductwork with variable-volume terminal boxes. Each VAV box shall have its own space temperature sensor controls tied to Facilities EMCS. The system shall be sized to supply approximately 1.25 CFM per square foot at maximum flow. Return air shall be through plenum spaces where possible.

11.3.2.2 Great Hall Area

Provide constant volume variable temperature heating and cooling.

11.3.3 Outdoor Air Requirements

Outside air shall be introduced through the VAV system and the high bay atrium makeup air units.

11.3.4 Ventilation Rates

All new design for proper ventilation shall be in accordance with the recommendations of the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. These values shall be based on terminal peak load occupancy.

11.3.5 Filtration

Outside air shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13, and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

11.3.6 AHU Controls

11.3.6.1 Occupied Space (VAV System)

Refer to 5.2 Sample Control Components and Requirements.

11.3.6.2 High Bay (Makeup Air System)

A. Provide similar basic controls and alarms as indicated for the VAV system.
B. Air volume shall be controlled by industrial-grade differential pressure controllers (auto zeroing type) in the occupied space to maintain positive pressure.
C. Heating coil controls shall maintain a 65°F leaving air temperature (adjustable).

D. Relief air fans shall be utilized for air relief and high bay ventilation to maintain a preset high bay space temperature.

11.3.7 Central Utility Plant

Chilled water and hot water shall be supplied from the CUP. Secondary pumping shall not be used for these facilities.

11.3.8 Plumbing Requirements

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code. Plumbing design shall consider the impact of future terminal expansion.

Provide plumbing fixtures for the physically disabled.

Refer to plumbing design parameters and basis of occupancy.

11.3.9 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of the National Fire Protection Agency (NFPA) Standards and the building code of the CCD. The following description of fire protection requirements is based on NFPA and FM Global, the current agency insurance underwriter.

A. Provide wet-pipe and dry-pipe sprinkler systems for this area.
B. Provide Class I standpipe system.
C. Provide an extinguisher at each station in the enclosed areas.
D. Provide manual pull-type fire alarm stations at exits.
E. All escalator and stair opening perimeters shall be provided with closely spaced sprinkler heads providing a water curtain.

11.3.10 Smoke Control

Atrium area shall be served by a separate smoke control system. Refer to the Life Safety DSM for requirements.

11.4 Passenger Terminal - Train Station Security

11.4.1 Indoor Design Conditions

A. Summer: 75°F
B. Winter: 70°F

11.4.2 Air Handling Systems

This area shall be air-conditioned with a VAV system. Refer to 3.0.1 Air Handling Systems.

The supply air ductwork system shall consist of medium-pressure ductwork with variable-volume terminal boxes. Each VAV box shall have its own space temperature sensor controls tied to Facilities EMCS. The system shall be sized to supply approximately 1.25 CFM per square foot at maximum flow. Return air shall be through plenum spaces where possible.

11.4.3 Ventilation Rates

All new design for proper ventilation shall be in accordance with the recommendations of the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. These values shall be based on average terminal load occupancy.

11.4.4 Filtration

Outside air shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13, and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

11.4.5 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.4.6 Central Utility Plant

Chilled water and hot water shall be supplied from the CUP. Secondary pumping shall not be used for these facilities.

11.4.7 Plumbing Requirements

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code. Plumbing design shall consider the impact of future terminal expansion.

Provide plumbing fixtures for the physically disabled.

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters and basis of occupancy.

11.4.8 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of National Fire Protection Agency (NFPA) Standards and the building code of the CCD. The following description of fire protection requirements is based on NFPA and FM Global, the current agency insurance underwriter.

A. Provide wet-pipe and dry-pipe sprinkler systems for this area.
B. Provide Class I standpipe system.
C. Provide an extinguisher at each station in the enclosed areas.
D. Provide manual pull-type fire alarm stations at exits.
E. All escalator and stair opening perimeters shall be provided with closely spaced sprinkler heads providing a water curtain.

11.4.9 Smoke Control

All public areas shall be served by a separate smoke control system. Refer to the Life Safety DSM for requirements.

11.5 Passenger Terminal - Train Station Exit Pavilions

11.5.1 Design Conditions

A. Summer: 75°F (50% RH Max) No Humidity Control
B. Winter: 70°F No Humidity Control

11.5.2 Air Handling Systems

This area shall be air-conditioned with a VAV system. Refer to 3.0.1 Air Handling Systems.

The supply air ductwork system shall consist of medium-pressure ductwork with variable-volume terminal boxes. Each VAV box shall have its own space temperature sensor controls tied to Facilities EMCS. The system shall be sized to supply approximately 1.25 CFM per square foot at maximum flow. Return air shall be through plenum spaces where possible.

11.5.3 Outdoor Air Requirements

Outside air shall be brought in through the AHU. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.5.4 Ventilation Rates

All new design for proper ventilation shall be in accordance with the recommendations of the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. These values shall be based on average terminal load occupancy.

11.5.5 Filtration

Outside air shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13, and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

11.5.6 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.5.7 Central Utility Plant

Chilled water and hot water shall be supplied from the CUP. Secondary pumping shall not be used for these facilities.

11.5.8 Plumbing Requirements

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code.

Plumbing design shall consider the impact of future terminal expansion.

Provide plumbing fixtures for the physically disabled.

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters and basis of occupancy.

11.5.9 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of National Fire Protection Agency (NFPA) Standards and the building code of the CCD. The following description of fire protection requirements is based on NFPA and FM Global, the current agency insurance underwriter.

A. Provide wet-pipe and dry-pipe sprinkler systems for this area.
B. Provide Class I standpipe system.
C. Provide an extinguisher at each station in the enclosed areas.
D. Provide manual pull-type fire alarm stations at exits.
E. All escalator and stair opening perimeters shall be provided with closely spaced sprinkler heads providing a water curtain.

11.5.10 Smoke Control

All public areas shall be served by a separate smoke control system. Refer to the Life Safety DSM for requirements.

11.6 Passenger Terminal - Train Station Loading Platforms

11.6.1 Design Conditions

A. Summer: 75°F (50% RH Max) No Humidity Control

B. Winter: 70°F No Humidity Control

11.6.2 Air Handling Systems

This area shall be air-conditioned with a VAV system. Refer to 3.0.1 Air Handling Systems.

The supply air ductwork system shall consist of medium-pressure ductwork with variable-volume terminal boxes. Each VAV box shall have its own space temperature sensor controls tied to Facilities EMCS. The system shall be sized to supply approximately 1.25 CFM per square foot at maximum flow. Return air shall be through plenum spaces where possible.

11.6.3 Outdoor Air Requirements

Outside air shall be brought in through the AHU. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.6.4 Ventilation Rates

All new design for proper ventilation shall be in accordance with the recommendations of the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. These values shall be based on average terminal load occupancy.

11.6.5 Filtration

Outside air shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13, and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

11.6.6 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.6.7 Central Utility Plant

Chilled water and hot water shall be supplied from the CUP. Secondary pumping shall not be used for these facilities.

11.6.8 Plumbing Requirements

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code.

Plumbing design shall consider the impact of future terminal expansion.

Provide plumbing fixtures for the physically disabled.

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters and basis of occupancy.

11.6.9 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of National Fire Protection Agency (NFPA) Standards and the building code of the CCD. The following description of fire protection requirements is based on NFPA and FM Global the current agency insurance underwriter.

A. Provide a wet-pipe and dry-pipe sprinkler systems for this area.

B. Provide Class I standpipe system.
C. Provide an extinguisher at each station in the enclosed areas.
D. Provide manual pull type fire alarm stations at exits.
E. All escalator and stair opening perimeters shall be provided with closely spaced sprinkler heads providing a water curtain.

11.7 Passenger Terminal - Concessions and Services

11.7.1 Design Conditions

A. Summer: 75°F (50% RH Max) No Humidity Control
B. Winter: 70°F No Humidity Control

11.7.2 Air Handling Systems

The base building air handling system has been designed to accommodate the following loads for Restaurant, Food Courts, Office, and Concession Spaces:

A. Basic Office, Retail, Airline Tenant: Exterior Load + 1.00 CFM/SF
B. Restaurant Tenant: Exterior + 1.25 CFM/SF for seating area. Kitchen to be conditioned with Tenant supplied makeup air system.
C. Bar Tenant: Exterior load + 1.25 CFM/SF
D. Food Court Tenant: Exterior load + 1.25 CFM/SF for seating areas. Source of makeup air shall be by each Tenant and coordinated between DEN and each Tenant.

The Tenant shall provide a complete HVAC system to meet loads that exceed the requirements listed above. The Tenant shall verify the heating and cooling loads from the perimeter, adjoining structures and adjacent spaces affecting the Tenant area. All Tenant areas in the terminal are in the interior spaces and are unaffected by the perimeter heating /cooling loads.

11.7.3 Outdoor Air Requirements

In general, outside air shall be brought in through the base building AHU and/or the kitchen ventilation system. Refer to 3.2 Ventilation Systems for ventilation requirements. The Tenant HVAC shall makeup a minimum of 100% of what is exhausted from the space.

11.7.4 Kitchen Exhaust

All kitchens shall be air conditioned. The exhaust requirements shall be determined by the cooking exhaust hoods installed within the facility. The kitchen exhaust system shall be designed in accordance with 3.5.6 Food and Beverage Tenant Equipment.

11.7.5 Ventilation Rates

The existing system ventilation was designed in accordance with American Society of Heating, Refrigeration, and Air Conditioning Engineers Standard (ASHRAE) 62-1989, Ventilation for Acceptable Indoor Air Quality. All new design for proper ventilation shall be in accordance with the recommendations of the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. Filtration.

11.7.6 Filtration

Outside air shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13 and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

11.7.7 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.7.8 Central Utility Plant

Chilled water and hot water shall be supplied from the CUP. Secondary pumping shall not be used for these facilities.

11.7.9 Plumbing Requirements

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code.

Plumbing design shall consider impact of future terminal expansion.

Provide plumbing fixtures for the physically disabled.

Provide grease trap interceptors for kitchen areas.

Provide gas-fired hot water heating system for kitchen requirements.

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters and basis of occupancy.

11.7.10 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of NFPA Standards and the building code for the CCD. The following description of fire protection requirements is based on NFPA.

A. Provide a wet-pipe sprinkler system for this area.
B. Provide Class I standpipe system.
C. Provide an extinguisher at each station in the enclosed areas.
D. Provide manual pull type fire alarm station at exits.
E. All escalator and stair opening perimeters shall be protected by providing closely spaced sprinkler heads to provide a water curtain.
F. Provide a pre-engineered carbon dioxide extinguishing system for the kitchen exhaust hoods in accordance with NFPA 12, Standard on Carbon Dioxide Extinguishing Systems. The system shall be capable of automatic detection with local or remote manual actuation. Accessories shall be installed for mechanical or electrical gas line shut-off applications. System shall be listed with Underwriters Laboratories, Inc. (Exception alternate extinguishing system types which are acceptable to the Denver Fire Prevention Bureau are allowed in lieu of CO2 but must complete all necessary steps as outlined)

11.7.11 Smoke Control

All public and Tenant areas shall be served by the base building smoke control system. Refer to the Life Safety DSM for requirements.

11.8 Passenger Terminal - Rest Rooms

11.8.1 Design Conditions

A. Summer: 75°F (No Humidity Control)
B. Winter: 70°F (No Humidity Control)

11.8.2 Air Handling Systems

This area shall be air conditioned with a VAV system.

In general, supply air shall be provided by the same AHU serving adjacent spaces.

11.8.3 Toilet Exhaust

The ventilation rate for all toilet room facilities shall be 0.5 CFM per square foot of floor area, six air changes per hour or as required by the latest edition of ASHRAE 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent.

11.8.4 Filtration

Outside air shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13, and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

11.8.5 Controls

Provide control logic to permit the following:

A. Space temperature

11.8.6 Central Utility Plant

Chilled water and hot water shall be supplied from the CUP.

11.8.7 Plumbing Requirements

Fixture count requirements shall be determined by the following:

A. Projected terminal occupancy.
B. Local code requirements.
C. Thirty-three percent of the passengers and 15% of visitors will use concourse facilities. Fifteen percent of passengers and visitors will use terminal facilities.
D. The ratio of men to women is estimated at 55% male/45% female.
E. Urinals shall be utilized in lieu of water closets to the maximum ratio allowed by the code.
F. Facilities for the physically disabled shall be provided in the terminal public restrooms.
G. All domestic hot and cold-water piping within conditioned areas shall be insulated. All piping subjected to freezing temperatures shall be insulated.
H. All lavatory faucets in public and private toilet rooms shall be provided with flow restriction devices on all outlets. Except for faucets on physically disabled fixtures.

The following is a partial list of plumbing fixtures required for this area:

A. Lavatories shall be wall-hung or counter-mounted.
B. Lavatories for the physically disabled can be wall-hung or counter-mounted with offset grid drain for wheelchairs.
C. Water closets, standard, and handicap shall be blow-out type.
D. Stop valves shall be provided on all fixtures, including water coolers.
E. Urinals
F. Floor drains and cleanouts.
G. All water coolers in public areas shall be barrier-free bi-level type.
H. Showers

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code.

Plumbing design shall consider the impact of future terminal expansion.

Provide plumbing fixtures for the physically disabled.

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters and basis of occupancy.

11.9 Passenger Terminal - Ground Transportation Level

11.9.1 Design Conditions

A. Summer: 75°F (50% RH Max.) No Humidity Control
B. Winter: 70°F No Humidity Control

11.9.2 Air Handling Systems

This area shall be air-conditioned with a VAV system. Refer to 3.0.1 Air Handling Systems.

The supply air ductwork system shall consist of medium-pressure ductwork with variable-volume terminal boxes. Each VAV box shall have its own space temperature sensor controls tied to Facilities EMCS. The system shall be sized to supply approximately 1.25 CFM per square foot at maximum flow. Return air shall be through plenum spaces where possible.

11.9.3 Perimeter Systems

The glass wall in the area shall be conditioned by a forced air perimeter system. This system shall be variable volume, heating, and cooling. This system shall not use fan-powered VAV terminal units for heating and cooling.

11.9.4 Outdoor Air Requirements

Outside air shall be brought in through the AHU. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.9.5 Ventilation Rates

All new design for proper ventilation shall be in accordance with the recommendations of the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. These values shall be based on terminal peak load occupancy.

11.9.6 Filtration

Outside air shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13, and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

11.9.7 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.9.8 Central Utility Plant

Chilled water and hot water shall be supplied from the CUP. Secondary pumping shall not be used for these facilities.

11.9.9 Plumbing Requirements

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code.

Plumbing design shall consider impact of future terminal expansion.

Provide plumbing fixtures for the physically disabled.

Refer to for plumbing design parameters and basis of occupancy.

11.9.10 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of National Fire Protection Agency (NFPA) Standards and the building code of the CCD. The following description of fire protection requirements is based on NFPA and FM Global the current agency insurance underwriter.

A. Provide a wet-pipe and dry-pipe sprinkler systems for this area.
B. Provide Class I standpipe system.
C. Provide an extinguisher at each station in the enclosed areas.
D. Provide manual pull type fire alarm stations at exits.
E. All escalator and stair opening perimeters shall be provided with closely spaced sprinkler heads providing a water curtain.

11.10 Passenger Terminal - Rental Car Level

11.10.1 Design Conditions

A. Summer: 75°F (50% RH Max.) No Humidity Control
B. Winter: 70°F No Humidity Control

11.10.2 Air Handling Systems

This area shall be air-conditioned with a VAV system. Refer to 3.0.1 Air Handling Systems.

The supply air ductwork system shall consist of medium-pressure ductwork with variable-volume terminal boxes. Each VAV box shall have its own space temperature sensor controls tied to Facilities EMCS. The system shall be sized to supply approximately 1.25 CFM per square foot at maximum flow. Return air shall be through plenum spaces where possible.

11.10.3 Perimeter Systems

The glass wall in the area shall be conditioned by a forced air perimeter system. This system shall be variable volume, heating, and cooling. This system shall not use fan-powered VAV terminal units for heating and cooling.

11.10.4 Outdoor Air Requirements

Outside air shall be brought in through the AHU. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.10.5 Ventilation Rates

All new design for proper ventilation shall be in accordance with the recommendations of the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. These values shall be based on terminal peak load occupancy.

11.10.6 Filtration

Outside air shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13, and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

11.10.7 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.10.8 Central Utility Plant

Chilled water and hot water shall be supplied from the CUP. Secondary pumping shall not be used for these facilities.

11.10.9 Plumbing Requirements

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code. Plumbing design shall consider the impact of future terminal expansion.

Provide plumbing fixtures for the physically disabled.

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters and basis of occupancy.

11.10.10 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of National Fire Protection Agency (NFPA) Standards and the building code of the CCD. The following description of fire protection requirements is based on NFPA and FM Global, the current agency insurance underwriter.

A. Provide wet-pipe and dry-pipe sprinkler systems for this area.
B. Provide Class I standpipe system.
C. Provide an extinguisher at each station in the enclosed areas.
D. Provide manual pull-type fire alarm stations at exits.
E. All escalator and stair opening perimeters shall be provided with closely spaced sprinkler heads providing a water curtain.

11.11 Passenger Terminal - Baggage Handling Level

11.11.1 Indoor Design Conditions

A. Summer: 95°F (50% RH Max) No Humidity Control
B. Winter: 40°F No Humidity Control

11.11.2 Air Handling Systems

This area shall be air tempered with constant volume direct-fired air-handling system interlocked with propeller exhaust fans. Refer to 3.0.1 Air Handling Systems.

11.11.3 Evaporative Cooling

Where the four-pipe distribution system is unavailable and acceptable air quality is available, evaporative cooling may be utilized (no back-up refrigeration unit) in lieu of refrigeration. Evaporative cooling may be the indirect or direct method of operation. By acceptable air quality, the air must be free of jet fuel exhaust fumes.

11.11.4 Outdoor Air Requirements

Outside air shall be brought in through the AHU. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.11.5 Ventilation Rates

All new design for proper ventilation shall be in accordance with the recommendations of the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International

Mechanical Code with City amendments, whichever is more stringent. Recommended average outside air ventilation rates shall be as follows:

A. All areas: 4 ACH

These values shall be based on terminal peak load occupancy.

11.11.6 Filtration

Outside air shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13, and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

11.11.7 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.11.8 Central Utility Plant

Chilled water and hot water shall be supplied from the CUP. Secondary pumping shall not be used for these facilities.

11.11.9 Plumbing Requirements

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code.

Plumbing design shall consider impact of future terminal expansion.

Provide plumbing fixtures for the physically disabled.

Refer to for plumbing design parameters and basis of occupancy.

11.11.10 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of National Fire Protection Agency (NFPA) Standards and the building code of the CCD. The following description of fire protection requirements is based on NFPA and FM Global, the current agency insurance underwriter.

A. Provide wet-pipe and dry-pipe sprinkler systems for this area.
B. Provide Class I standpipe system.
C. Provide an extinguisher at each station in the enclosed areas.
D. Provide manual pull-type fire alarm stations at exits.
E. All escalator and stair opening perimeters shall be provided with closely spaced sprinkler heads providing a water curtain.

11.12 Passenger Terminal - Baggage Handling Level – Baggage Screening Areas

11.12.1 Design Conditions

A. Summer: 75°F (50% RH Max) No Humidity Control
B. Winter: 70°F No Humidity Control

11.12.2 Air Handling Systems

The existing air handling systems in the baggage handling areas is not designed to maintain office environment conditions.

Screening areas, which require year-round conditioning, may be connected to the CUP chilled water system for cooling and heating. Gas-fired DX units may also be used.

11.12.3 Outdoor Air Requirements

In general, each space must provide outside air in accordance with 3.2 Ventilation Systems for ventilation requirements.

11.12.4 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent.

11.12.5 Filtration

Outside air shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13, and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

11.12.6 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.12.7 Central Utility Plant

Chilled water and hot water may be supplied from the CUP. Secondary pumping shall not be used for these facilities.

11.12.8 Plumbing Requirements

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code.

Plumbing design shall consider impact of future terminal expansion.

Provide plumbing fixtures for the physically disabled.

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters and basis of occupancy.

11.12.9 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of National Fire Protection Agency (NFPA) Standards and the building code of the CCD. The following description of fire protection requirements is based on NFPA and FM Global, the current agency insurance underwriter.

A. Provide wet-pipe and dry-pipe sprinkler systems for this area.
B. Provide Class I standpipe system.
C. Provide an extinguisher at each station in the enclosed areas.
D. Provide manual pull-type fire alarm stations at exits.
E. All escalator and stair opening perimeters shall be provided with closely spaced sprinkler heads providing a water curtain.

11.13 Passenger Terminal – Tenant Spaces

Tenant spaces include Restaurants, Food Courts, Offices, and Concessions.

11.13.1 Design Conditions

A. Summer: 75°F (50% RH Max) No Humidity Control

B. Winter: 70°F No Humidity Control

11.13.2 Air Handling Systems

The base building air handling system has been designed to accommodate the following loads for Restaurants, Food Courts, Office, and Concession Spaces:

A. Basic Office, Retail, Airline Tenant

Exterior Load + 1.00 CFM/SF

B. Restaurant Tenant

Exterior + 1.25 CFM/SF for seating area

Kitchen to be conditioned with Tenant supplied makeup air system

C. Bar Tenant

Exterior Load + 1.25 CFM/SF

D. Food Court Tenant

Exterior load + 1.25 CFM/SF for seating areas

Source of makeup air shall be by each Tenant and coordinated between DEN and each Tenant.

The Tenant shall provide a complete HVAC system to meet loads that exceed the requirements listed above. The Tenant shall verify the heating and cooling loads from the perimeter, adjoining structures, and adjacent spaces affecting the Tenant area. All Tenant areas in the terminal are in the interior spaces and are unaffected by the perimeter heating/cooling loads.

11.13.3 Perimeter Systems

The glass wall in the area shall be conditioned by the base building system.

11.13.4 Outdoor Air Requirements

In general, outside air shall be brought in through the base building AHU and/or the kitchen ventilation system. The Tenant HVAC shall make up a minimum of 100% of what is exhausted from the space. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.13.5 Ventilation Rates

The existing system ventilation was designed in accordance with the American Society of Heating, Refrigeration, and Air Conditioning Engineers Standard (ASHRAE) 62-1989, Ventilation for Acceptable Indoor Air Quality. All new design for proper ventilation shall be in accordance with the recommendations of the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. All kitchen areas shall have a separate exhaust fan.

11.13.6 Kitchen Exhaust

All kitchens shall be air-conditioned. The exhaust requirements shall be determined by the cooking exhaust hoods installed within the facility. The kitchen exhaust system shall be designed in accordance with 3.5.6 Food and Beverage Tenant Equipment.

11.13.7 Filtration

Outside air shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13, and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

11.13.8 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.13.9 Central Utility Plant

Chilled water and hot water connections are not available for Tenants in this area.

11.13.10 Plumbing Requirements

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code.

Plumbing design shall consider the impact of future terminal expansion.

Provide plumbing fixtures for the physically disabled.

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters and basis of occupancy.

11.13.11 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of National Fire Protection Agency (NFPA) Standards and the building code of the CCD. The following description of fire protection requirements is based on NFPA and FM Global, the current agency insurance underwriter.

A. Provide wet-pipe and dry-pipe sprinkler systems for this area.
B. Provide Class I standpipe system.
C. Provide an extinguisher at each station in the enclosed areas.
D. Provide manual pull-type fire alarm stations at exits.
E. All escalator and stair opening perimeters shall be provided with closely spaced sprinkler heads providing a water curtain.

11.13.12 Simplicity of Systems

Where possible, Consultants shall reduce or eliminate redundant systems and equipment or sequences of operation. DEN staff understand that certain provisions in the Design Standards Manuals, codes and regulations, and project-specific requirements or constraints may necessitate the use of redundant systems, equipment, or sequences of operation. In instances where redundant equipment is located outside of tenant lease bounds, the Consultant shall provide a narrative describing what requirement necessitates the use of the redundant systems, equipment, or sequences of operation on the mechanical notes or plumbing notes sheet of the drawings.

For any food service tenant space with an exhaust air quantity over 5000 CFM, there shall be one (1) make-up air unit for every one (1) kitchen exhaust fan.

11.14 Passenger Terminal – Electrical Rooms

11.14.1 Design Conditions

A. Summer: 95°F No Humidity Control (ventilation only)
B. Winter: 40°F No Humidity Control (ventilation only)
C. Maintain positive space pressure for dust control.

11.14.2 Air Handling Systems

This facility shall be air-conditioned with a single zone system or connected to the base building system.

Single zone units shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected for sound control. AHUs shall contain a throwaway filter section. Air Handlers shall be located outside of the electrical room and in locations that allow for full maintenance of the units. Supply and return air shall be ducted in a low-pressure type system. Refer to 3.0.1 Air Handling Systems for air handling system requirements.

11.14.3 Outdoor Air Requirements

None required.

11.14.4 Filtration

Outside air or air from a dirty area (baggage tunnel, parking garages, apron, etc.) shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7.

11.14.5 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.14.6 Central Utility Plant

Chilled water connections are available for conditioning equipment but shall not be run inside the electrical room.

11.14.7 Plumbing Requirements

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code.

Plumbing piping that is either new or existing shall not run through an electrical room. Relocate existing piping to avoid the electrical room.

If sloped piping cannot be relocated, a sheet metal gutter under the pipe shall be provided, the gutter system shall be fully designed and detailed on the contract documents. No component of the gutter shall be left to the contractor’s discretion. Details shall accommodate the following:

A. Gutters shall be supported independently of the sloped piping.
B. Structural supports and connections to the building structure.
C. Details are to include minimum slope, drain location, sheet metal gauge, and drain connection to the gutter.
D. Dedicated piping from the gutter low points to an open site location. Open site termination shall include signage defining procedures in the event of a leak. Sign shall read, “If water is observed from the pipe below (or above), immediately contact Maintenance Control at (303) 342- 2800”.
E. Dedicated drain piping to extent to outside of the room and be protected by a secondary gutter.
F. Do not route any drain piping over switchgear, transformers, or other electrical equipment.

Gutter shall not block or inhibit access to surrounding systems.

11.14.8 Fire Protection

No sprinkler system shall be installed. Provide two-hour rated room to meet requirements of NPFA 13. Refer to the Electrical DSM for fire alarm requirements.

11.15 Passenger Terminal – Telecommunications and UPS Rooms

11.15.1 Design Conditions

A. Summer: 68°F, 65% RH max, 40% RH min
B. Winter: 68°F, 65% RH max, 40% RH min
C. Maintain positive space pressure for dust control.

11.15.2 Air Handling Systems

This facility shall be air-conditioned with single-zone DX system.

Single zone units shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected for sound control. AHUs shall contain a throwaway filter section. Air Handlers shall be located outside of the room and in locations that allow for full maintenance of the units. Supply and return air shall be ducted in a low-pressure type system. Refer to 3.0.1 Air Handling Systems for air handling system requirements.

11.15.3 Outdoor Air Requirements

None required.

11.15.4 Filtration

Outside air or air from a dirty area (baggage tunnel, parking garages, apron, etc.) shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7.

11.15.5 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.15.6 Central Utility Plant

Chilled water and hot water may be supplied from the CUP. Secondary pumping shall not be used for these facilities.

11.15.7 Plumbing Requirements

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code.

Plumbing piping that is either new or existing shall not run through the Telecommunications and UPS Rooms or an associated electrical room. Relocate existing piping to avoid the rooms.

If sloped piping cannot be relocated, a sheet metal gutter under the pipe shall be provided. The gutter system shall be fully designed and detailed on the contract documents. No component of the gutter shall be left to the contractor's discretion. Details shall accommodate the following:

A. Gutters shall be supported independently of the sloped piping.
B. Structural supports and connections to the building structure.
C. Details are to include minimum slope, drain location, sheet metal gauge, and drain connection to the gutter.
D. Dedicated piping from the gutter low points to an open site location. Open site termination shall include signage defining procedures in the event of a leak. Sign shall read, "If water is observed from the pipe below (or above), immediately contact Maintenance Control at (303) 342-2800".
E. Dedicated drain piping to extent to outside of the room and be protected by a secondary gutter.
F. Do not route any drain piping over switchgear, transformers, or other electrical equipment.

Gutter shall not block or inhibit access to surrounding systems.

11.15.8 Fire Protection

No sprinkler system shall be installed. Provide a two-hour rated room to meet the requirements of NPFA 13. Refer to the Electrical DSM for fire alarm requirements.

11.16 International Concourse

11.16.1 Design Conditions

A. Summer: 75°F (No Humidity Control)

B. Winter: 70°F

11.16.2 Air Handling Systems

This area shall be air-conditioned with a VAV system. Refer to 3.0.1 Air Handling Systems.

The supply air ductwork system shall consist of medium-pressure ductwork with variable-volume terminal boxes. Each VAV box shall have its own space temperature sensor controls tied to Facilities EMCS. The system shall be sized to supply approximately 1.25 CFM per square foot at maximum flow. Return air shall be through plenum spaces where possible.

11.16.3 Perimeter Systems

The glass walls in the area shall be conditioned by a forced air perimeter system. This system shall be variable volume with a minimum setpoint and use hot, chilled water reheat coils. Sill or overhead diffusers shall be used (providing overhead diffusers are not over 9 ft. 6 in. AFF).

Fan-powered boxes shall not be used.

11.16.4 Air Curtains

Overhead fan-coil units shall be used at each jetway entrance. The fan-coil units shall be activated whenever the door is opened with a 30-second time delay, and the supply air temperature is controlled from a space thermostat.

11.16.5 Outdoor Air Requirements

Outside air shall be brought in through the AHU. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.16.6 Toilet Exhaust

The ventilation rate for all toilet room facilities shall be 0.5 CFM per square foot of floor area, 6 air changes per hour or as required by the latest edition of ASHRAE 62.1, whichever is more stringent.

11.16.7 Kitchen Exhaust

All kitchens shall be air conditioned. The exhaust levels shall be determined by the cooking exhaust hood requirements within the facility. The kitchen exhaust system shall be designed in accordance with 3.5.6 Food and Beverage Tenant Equipment.

11.16.8 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. These values shall be based on terminal peak load occupancy.

11.16.9 Filtration

Outside air shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13, and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

11.16.10 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.16.11 Central Utility Plant

Chilled water and hot water shall be supplied from the CUP for building heating and cooling. Secondary pumping shall not be used for these facilities.

11.16.12 Plumbing Requirements

The basis for plumbing fixture count is based on the following criteria:

A. Projected concourse occupancy.
B. Local code requirements.
C. Thirty-three percent of the passengers and 15% of visitors shall use concourse facilities.
D. The ratio of men to women is estimated at 55% male/45% female.
E. Urinals shall be utilized in lieu of water closets to the maximum ratio allowed by the code.
F. Facilities for the physically disabled shall be provided in the terminal public restrooms.

All domestic hot and cold water and storm drainage piping within conditioned areas shall be insulated. All piping subjected to freezing temperatures shall be insulated.

All lavatory faucets in public and private toilet rooms shall be provided with flow restriction devices on all outlets, except for faucets on physically disabled fixtures.

The following is a partial list of plumbing fixtures required for this area:

A. Lavatories shall be wall-hung or counter-mounted.
B. Lavatories for the physically disabled can be wall-hung or counter-mounted with offset grid drain for wheelchairs.
C. Water closets, standard, and handicap shall be blow-out type.
D. Stop valves shall be provided on all fixtures, including water coolers.
E. Urinals
F. Floor drains and cleanouts.
G. All water coolers in public areas shall be barrier-free bi-level type.
H. Showers
I. Sand traps and oil separators.
J. Industrial waste sewer system.
K. Hot water heater.
L. All domestic water connections to mechanical systems shall be protected from backflow.

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code.

Plumbing design shall consider the impact of future terminal expansion.

Provide plumbing fixtures for the physically disabled.

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters and basis of occupancy.

11.16.13 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of NFPA Standards and building code of the CCD. The following description of fire protection requirements is based on NFPA.

A. Provide a wet-pipe sprinkler system for this area.
B. Provide a Class I standpipe system (unless concourse width exceeds 100 feet) with extinguishers throughout the area.
C. Provide manual pull type fire alarm station at exits.
D. All escalator and stair opening perimeters shall be protected by providing closely spaced sprinkler heads to provide a water curtain.
E. Single facilities larger than 1500 Square feet requires fire sprinkler and fire alarm systems per the requirements of Denver Fire Prevention Bureau, FM Global and NFPA.

11.16.14 Smoke Control

All public and Tenant areas shall be served by a separate smoke control system. Refer to the Life Safety DSM for requirements.

11.17 Domestic Concourse

11.17.1 Design Conditions

A. Summer: 75°F (No Humidity Control)
B. Winter: 70°F

11.17.2 Air Handling Systems

This area shall be air conditioned with a VAV system. Refer to 3.0.1 Air Handling Systems.

The supply air ductwork system shall consist of medium pressure ductwork with variable volume terminal boxes. Each VAV box shall have its own space temperature sensor controls tied to Facilities EMCS. The system shall be sized to supply approximately 1.25 CFM per square foot at maximum flow. Return air shall be through plenum spaces where possible.

11.17.3 Perimeter Systems

The glass walls in the area shall be conditioned by a forced air perimeter system. This system shall be variable volume with a minimum setpoint and use hot and chilled water coils. Sill or overhead diffusers shall be used (providing overhead diffusers are not over 9 feet 6 inches AFF).

Fan powered boxes shall not be used.

11.17.4 Air Curtains

Overhead fan-coil units shall be used at each jetway entrance. The fan-coil units shall be activated whenever the door is opened with a 30-second time delay and the supply air temperature controlled from a space thermostat.

11.17.5 Outdoor Air Requirements

Outside air shall be brought in through the AHU. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.17.6 Toilet Exhaust

The ventilation rate for all toilet room facilities shall be 0.5 CFM per square foot of floor area, 6 air changes per hour or as required by the latest edition of ASHRAE 62.1, whichever is more stringent.

11.17.7 Kitchen Exhaust

All kitchens shall be air conditioned. The exhaust levels shall be determined by the cooking exhaust hood requirements within the facility. The kitchen exhaust system shall be designed in accordance with 3.5.6 Food and Beverage Tenant Equipment.

11.17.8 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. These values shall be based on terminal peak load occupancy.

11.17.9 Filtration

Outside air shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13 and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

11.17.10 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.17.11 Central Utility Plant

Chilled water and hot water shall be supplied from the CUP for building heating and cooling. Secondary pumping shall not be used for these facilities.

11.17.12 Plumbing Requirements

The basis for plumbing fixture count is based on the following criteria:

A. Projected concourse occupancy.
B. Local code requirements.
C. Thirty-three percent of the passengers and 15% of visitors shall use concourse facilities.
D. The ratio of men to women is estimated at 55% male/45% female.
E. Urinals shall be utilized in lieu of water closets to the maximum ratio allowed by code.
F. Facilities for the physically disabled shall be provided in the terminal public restrooms.

All domestic hot- and cold-water, and storm drainage piping within conditioned areas shall be insulated. All piping subjected to freezing temperatures shall be insulated.

All lavatory faucets in public and private toilet rooms shall be provided with flow restriction devices on all outlets, except for faucets on physically handicap fixtures.

The following is a partial list of plumbing fixtures required for this area:

A. Lavatories shall be wall hung or counter mounted.
B. Lavatories for the physically disabled can be wall hung or counter mounted with offset grid drain for wheelchairs.
C. Water closets, standard and handicap, shall be blow out type.
D. Stop valves shall be provided on all fixtures including water coolers.
E. Urinals
F. Floor drains and cleanouts.
G. Water coolers shall be barrier free bi-level type in public areas.
H. Showers

I. Sand traps and oil separators.

J. Industrial waste sewer system.

K. Hot water heater

All domestic water connections, to mechanical systems, shall be protected from backflow.

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code.

Plumbing design shall consider impact of future terminal expansion.

Provide plumbing fixtures for the physically disabled.

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters and basis of occupancy.

11.17.13 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of National Fire Protection Agency (NFPA) Standards and the building code of the CCD. The following description of fire protection requirements is based on NFPA and FM Global the current agency insurance underwriter.

A. Provide a wet-pipe and dry-pipe sprinkler systems for this area.

B. Provide Class I standpipe system.

C. Provide an extinguisher at each station in the enclosed areas.

D. Provide manual pull type fire alarm stations at exits.

E. All escalator and stair opening perimeters shall be provided with closely spaced sprinkler heads providing a water curtain.

11.17.14 Concourse A Ground Load Facility

The base building HVAC systems for Concourse Ground Load Facility do not have extra capacity for Tenant spaces; additionally, there is no hydronic heating or cooling available in the Concourse A Ground Load Facility. All Tenants shall provide standalone HVAC systems for each space. Roof mounted equipment is acceptable in this area provided that it meets minimum code clearances and structural requirements of the Ground Load Facility Building. Locations of exhaust fans and exhaust openings shall be approved in writing by the DEN Mechanical Engineer.

11.17.15 Concourse B East Regional Jet Facility

The base building HVAC systems for Concourse B Regional Jet Facility do not have extra capacity for Tenant spaces. All Tenants shall provide standalone HVAC systems for each space. Roof mounted equipment is acceptable in this area provided that it meets minimum code clearances. Locations of exhaust fans and exhaust openings shall be approved in writing by the DEN Mechanical Engineer.

11.18 Domestic Concourse – Tenant Spaces

11.18.1 Design Conditions

A. Summer: 75°F (50% RH Max) No Humidity Control

B. Winter: 70°F No Humidity Control

11.18.2 Air Handling Systems

The base building air handling system has been designed to accommodate the following loads for Restaurant, Food Courts, Office, and Concession Spaces:

A. Basic Office, Retail, Airline Tenant: Exterior Load + 1.00 CFM/SF

B. Restaurant Tenant: Exterior + 1.25 CFM/SF for seating area. Kitchen to be conditioned with Tenant supplied makeup air system.

C. Bar Tenant: Exterior load + 1.25 CFM/SF

D. Food Court Tenant: Exterior load + 1.25 CFM/SF for seating areas. Source of makeup air shall be by each Tenant and coordinated between DEN and each Tenant.

E. Concourse B Regional Jet Facility: No Tenant HVAC (hydronic on airside) accommodations have been made. Tenant shall provide a complete stand-alone HVAC system.

The Tenant shall provide a complete HVAC system to meet loads that exceed the requirements listed above. The Tenant shall verify the heating and cooling loads from the perimeter, adjoining structures and adjacent spaces affecting the Tenant area.

11.18.3 Perimeter Systems

The glass wall in the area shall be conditioned by the base building system.

11.18.4 Outdoor Air Requirements

In general, outside air shall be brought in through the base building AHU and/or the kitchen ventilation system. Refer to 3.2 Ventilation Systems for ventilation requirements. The Tenant HVAC shall makeup a minimum of 100% of what is exhausted from the space.

11.18.5 Ventilation Rates

The existing base building system ventilation was designed in accordance with American Society of Heating, Refrigeration, and Air Conditioning Engineers Standard (ASHRAE) 62-1989, Ventilation for Acceptable Indoor Air Quality. All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent.

11.18.6 Kitchen Exhaust

All kitchens shall be air conditioned. The exhaust requirements shall be determined by the cooking exhaust hoods installed within the facility. The kitchen exhaust system shall be designed in accordance with 3.5.6 Food and Beverage Tenant Equipment.

11.18.7 Filtration

Outside air shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13 and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

11.18.8 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.18.9 Central Utility Plant

Chilled water and hot water connections are not available for Tenants in this area.

11.18.10 Plumbing Requirements

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code.

Plumbing design shall consider impact of future terminal expansion.

Provide plumbing fixtures for the physically disabled.

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters and basis of occupancy.

11.18.11 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of National Fire Protection Agency (NFPA) Standards and the building code of the CCD. The following description of fire protection requirements is based on NFPA and FM Global the current agency insurance underwriter.

A. Provide a wet-pipe and dry-pipe sprinkler systems for this area.
B. Provide Class I standpipe system.
C. Provide an extinguisher at each station in the enclosed areas.
D. Provide manual pull type fire alarm stations at exits.
E. All escalator and stair opening perimeters shall be provided with closely spaced sprinkler heads providing a water curtain.

11.18.12 Smoke Control

All public and Tenant areas shall be served by a separate smoke control system. Refer to the Life Safety DSM for requirements.

11.18.13 Simplicity of Systems

Where possible, Consultants shall reduce or eliminate redundant systems and equipment, or sequences of operation. DEN staff understand that certain provisions in the Design Standards Manuals, codes and regulations, and project specific requirements or constraints may necessitate the use of redundant systems, equipment, or sequences of operation. In instances where redundant equipment is located outside of tenant lease bounds, the Consultant shall provide a narrative describing what requirement necessitates the use of the redundant systems, equipment, or sequences of operation on the mechanical notes or plumbing notes sheet of the drawings.

For any food service tenant space with an exhaust air quantity over 5000 CFM, there shall be one (1) make-up air unit for every one (1) kitchen exhaust fan.

11.19 Domestic Concourse – Electrical Rooms

11.19.1 Design Conditions

A. Summer: 95°F No Humidity Control
B. Winter: 95°F No Humidity Control
C. Maintain positive space pressure for dust control.

11.19.2 Air Handling Systems

This facility shall be air conditioned with single zone system or connected to base building system.

Single zone units shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected for sound control. AHUs shall contain and a throwaway filter section. Air Handlers shall be located outside of the electrical room and in locations that allow for full maintenance of the units. Supply and return air shall be ducted in a low-pressure type system. Refer to 3.0.1 Air Handling Systems for air handling system requirements.

11.19.3 Outdoor Air Requirements

Not required.

11.19.4 Filtration

Outside air or air from a dirty area (baggage tunnel, parking garages, apron, etc.) shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7.

11.19.5 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.19.6 Central Utility Plant

Chilled water connections are available for conditioning equipment but shall not be run inside the electrical room.

11.19.7 Plumbing Requirements

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CC building code.

Plumbing piping that is either new or existing shall not run through an electrical room. Relocate existing piping to avoid the electrical room.

If sloped piping cannot be relocated, a sheet metal gutter under the pipe shall be provided. The gutter system shall be fully designed and detailed on the contract documents. No component of the gutter shall be left to the contractor's discretion. Details shall accommodate the following:

A. Gutters shall be supported independently of the sloped piping.
B. Structural supports and connections to the building structure.
C. Details are to include minimum slope, drain location, sheet metal gauge, and drain connection to the gutter.
D. Dedicated piping from the gutter low points to an open site location. Open site termination shall include signage defining procedures in the event of a leak. Sign shall read, "If water is observed from the pipe below (or above), immediately contact Maintenance Control at (303) 342-2800".
E. Dedicated drain piping to extent outside of the room and be protected by a secondary gutter.
F. Do not route any drain piping over switchgear, transformers, or other electrical equipment.

Gutter shall not block or inhibit access to surrounding systems.

11.19.8 Fire Protection

No sprinkler system shall be installed. Provide two-hour rated room to meet requirements of NPFA 13. Refer to the Electrical DSM for fire alarm requirements.

11.20 Domestic Concourse – Telecommunications and UPS Rooms

11.20.1 Design Conditions

A. Summer: 68°F, 65% RH max
B. Winter: 68°F
C. Maintain positive space pressure for dust control.

11.20.2 Air Handling Systems

This facility shall be air conditioned with single zone DX system.

Single zone units shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected for sound control. AHUs shall contain and a throwaway filter section. Air Handlers shall be located outside of the room and in locations that allow for full maintenance of the units. Supply and return air shall be ducted in a low-pressure type system.

Refer to 3.0.1 Air Handling Systems.

11.20.3 Outdoor Air Requirements

Not required.

11.20.4 Filtration

Outside air or air from a dirty area (baggage tunnel, parking garages, apron, etc.) shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7.

11.20.5 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.20.6 Central Utility Plant

Chilled water and hot water shall be supplied from the CUP for building heating and cooling. Secondary pumping shall not be used for these facilities.

11.20.7 Plumbing Requirements

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code.

Plumbing piping that is either new or existing shall not run through the Telecommunications and UPS Rooms or an associated electrical room. Relocate existing piping to avoid the rooms.

If sloped piping cannot be relocated, a sheet metal gutter under the pipe shall be provided. The gutter system shall be fully designed and detailed on the contract documents. No component of the gutter shall be left to the contractor's discretion. Details shall accommodate the following:

A. Gutters shall be supported independently of the sloped piping.
B. Structural supports and connections to the building structure.
C. Details are to include minimum slope, drain location, sheet metal gauge, and drain connection to the gutter.
D. Dedicated piping from the gutter low points to an open site location. Open site termination include signage defining procedures in the event of a leak. Sign shall read, "If water is observed from the pipe below (or above), immediately contact Maintenance Control at (303) 342-2800".
E. Dedicated drain piping to extent to outside of the room and be protected by a secondary gutter.
F. Do not route any drain piping over switchgear, transformers, or other electrical equipment.

Gutter shall not block or inhibit access to surrounding systems.

11.20.8 Fire Protection

No sprinkler system shall be installed. Provide two-hour rated room to meet requirements of NPFA 13. Refer to the Electrical DSM for fire alarm requirements.

11.21 Domestic Concourse – Service Animal Relief Areas (SARA)

11.21.1 Design Conditions

A. Summer: 75°F (50% RH Max) No Humidity Control
B. Winter: 70°F No Humidity Control
C. Maintain Negative Pressure for Odor Control

11.21.2 Air Handling System

This area shall be air conditioned with a VAV system. Refer to 3.0.1 Air Handling Systems.

The supply air ductwork system shall consist of medium pressure ductwork with variable volume terminal boxes. Each VAV box shall have its own space temperature sensor controls tied to Facilities EMCS. The system shall be sized to supply approximately 1.25 CFM per square foot at maximum flow. Return air shall be through plenum spaces where possible.

11.21.3 Perimeter Systems

The glass walls in the area shall be conditioned by a forced air perimeter system. This system shall be variable volume with a minimum setpoint and use hot and chilled water coils. Sill or overheard diffusers shall be used (providing overhead diffusers are not over 9 feet 6 inches AFF).

Fan powered boxes shall not be permitted.

11.21.4 Exhaust

The ventilation rate for all SARA room facilities shall be at least 10 air changes per hour or as required by the latest edition of ASHRAE, 62.1, whichever is more stringent.

11.21.5 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. These values shall be based on terminal peak load occupancy.

11.21.6 Filtration

Outside air shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13 and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

11.21.7 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.21.8 Central Utility Plant

Chilled water and hot water shall be supplied from the CUP for building heating and cooling. Secondary pumping shall not be used for these facilities.

11.21.9 Plumbing Requirements

The basis of plumbing fixture count is based on the following criteria:

All domestic hot- and cold-water, and storm drainage piping within conditioned areas shall be insulated. All piping subjected to freezing temperatures shall be insulated.

The following is a partial list of plumbing fixtures required for this area:

A. Hot water tops
B. Cold water tops
C. Floor drains and cleanouts
D. Hot water heater

All domestic water connections, to mechanical systems, shall be protected from backflow.

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code.

Plumbing design shall consider impact of future terminal expansion.

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters and basis of occupancy.

11.21.10 Fire Protection

The fire protection system shall be provided in accordance with the latest edition of National Fire Protection Agency (NFPA) Standards and the building code of the CCD. The following description of fire protection requirements is based on NFPA and FM Global the current agency insurance underwriter.

A. Provide a wet-pipe and dry-pipe sprinkler systems for this area.
B. Provide Class I standpipe system.
C. Provide an extinguisher at each station in the enclosed areas.
D. Provide manual pull type fire alarm stations at exits.

11.22 Control Tower

11.22.1 Design Conditions

A. Summer: 75°F (No Humidity Control)
   75°F for Control Cab
B. Winter: 70°F (Humidification in electronic equipment spaces only)

11.22.2 Air Handling Systems

This facility shall be air conditioned with single zone systems.

Each unit shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected for sound control. AHUs shall contain cooling and heating coils (includes cooling only units), an optional electronic air filter section, and a throwaway filter section. Provide a mixed air plenum for outside air and return air duct damper connections on units 2000 CFM and above. Heating coils shall be located upstream of the cooling coils with space in between the two coil sections to enable access for maintenance and inspection.

Supply and return air shall be ducted in a low-pressure type system.

Refer to 3.0.1 Air Handling Systems for air handling system requirements.

11.22.3 Perimeter Systems

In the control cab, the glass wall shall be covered by a forced air perimeter system. This system shall be constant volume, variable temperature. It shall utilize sill diffusers to counteract downdrafts and provide good air circulation.

11.22.4 Computer and Electronic Equipment Rooms

Computer rooms, which require year-round cooling, may be connected to the CUP chilled water system for cooling. In addition, critical computer and/or communications rooms shall have their own DX cooling system for winter operation. The system shall have factory installed and wired controls for chilled water and DX cooling coils, heating coils, dehumidification, and humidification. The unit shall have an electric, steam generating humidifier with controls to limit space humidity to 50% maximum.

Plumbing piping that is either new or existing shall not run through the Computer and Electronic Equipment Rooms or an associated electrical room. Relocate existing piping to avoid rooms.

If sloped piping cannot be relocated, a sheet metal gutter under the pipe shall be provided. The gutter system shall be fully designed and detailed on the contract documents. No component of the gutter shall be left to the contractor’s discretion. Details shall accommodate the following:

A. Gutters shall be supported independently of the sloped piping.
B. Structural supports and connections to the building structure.
C. Details are to include minimum slope, drain location, sheet metal gauge, and drain connection to the gutter.
D. Dedicated piping from the gutter low points to an open site location. Open site termination shall include signage defining procedures in the event of a leak. Sign shall read, “If water is observed from the pipe below (or above), immediately contact Maintenance Control at (303) 342-2800”.
E. Dedicated drain piping to extent to outside of the room and be protected by a secondary gutter.
F. Do not route any drain piping over switchgear, transformers, or other electrical equipment.

Gutter shall not block or inhibit access to surrounding systems.

11.22.5 Outdoor Air Requirements

Outside air shall be brought in through the AHU. Refer to 3.2 Ventilation Systems for ventilation requirements. Locate outside air intakes high and away from vehicle or jet exhaust, to the greatest extent possible.

11.22.6 Toilet Exhaust

The ventilation rate for all toilet room facilities shall be 0.5 CFM per square foot of floor area or as prescribed by the latest edition of ASHRAE 62.1, whichever is more stringent.

11.22.7 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent.

11.22.8 Filtration

Outside air should be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13 and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

11.22.9 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.22.10 Plumbing Requirements

All plumbing systems shall conform to the requirements of the IPC as adopted and modified by the CCD building code. Refer to for plumbing design parameters. The following is a partial list of plumbing fixtures required for this area:

A. Lavatories- wall hung or counter mounted
B. Water closets, standard and handicap
C. Stop valves on all fixtures
D. Urinals
E. Floor drains and cleanouts
F. Water coolers

11.22.11 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of NFPA Standards and CCD building codes. The following description of fire protection requirements is based on NFPA.

A. Provide a wet-pipe sprinkler system for all areas unless specific requirements prohibit use in electronic equipment areas. In these cases, utilize Halon systems mentioned below.
B. Intergen or FM-200 systems in the above defined mentioned below. The system shall have manual and automatic actuation, warning alarms, flashing signs indicating halon discharge, backup systems, and all other fittings and appurtenances necessary for NFPA compliance.
C. Provide a Class I standpipe system with extinguisher at each station in the area.
D. Provide manual pull type fire alarm stations at exits.

11.22.12 Smoke Control

Smoke control is not required for this area.

11.23 Hotel

11.23.1 Design Conditions

A. Summer: 75°F (50% RH Max.)
B. Winter: 70°F (No Humidity Control)

11.23.2 Air Handling Systems

11.23.2.1 Meeting Rooms, Restaurants, Public Areas

These areas shall be air conditioned with VAV systems. Each unit shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected in the lower range for sound control. In addition, systems shall contain cooling and heating coil sections (includes cooling only units), an electronic air filter section (Cosa-Tron or equal), a throwaway bag-type filter section, and air blender section to eliminate air stratification, and a mixed air plenum for outside air and return air duct damper connections.

The supply air ductwork system shall consist of low-pressure ductwork with variable volume terminal boxes. Each VAV box shall have its own temperature sensor and controls tied to the Facilities EMCS. The system shall be sized to supply approximately 1.25 CFM per square foot at maximum flow. Return air shall be through ceiling plenums where possible.

11.23.2.2 Guest Rooms

Each room shall contain its own 4-pipe fan-coil unit (not through-the-wall units). The fan coil units shall have manually adjusted temperature controls. The heating and cooling coils shall modulate hydronic flow with 2-way pressure independent control valves to maintain the room thermostat setting. Provide with dry-type throwaway filters. Fan coil units shall be furnished and installed to provide an NC-35 noise level in the room.

11.23.2.3 Kitchens

Provide constant volume AHUs with the same unit components mentioned above for the VAV AHUs.

Refer to 3.0.1 Air Handling Systems for air handling system requirements.

11.23.3 Perimeter Systems

Any expanse of glass wall in the area shall be conditioned by a forced air perimeter system. This system should utilize sill diffusers to counteract downdrafts during cold weather.

11.23.4 Air Curtains

Air curtains shall be provided for use at main entrances. Overhead fan-coil units shall be used at each entrance.

11.23.5 Outdoor Air Requirements

Refer to- for ventilation requirements.

Outside air shall be brought in through the AHUs. Guest room floors shall have a separate makeup air unit to pressurize the corridors and guest rooms.

11.23.6 Toilet Exhaust

The ventilation rate for all toilet room facilities shall be 0.5 CFM per square foot of floor area, 6 air changes per hour or as required by the latest edition of ASHRAE 62.1, whichever is more stringent.

11.23.7 Kitchen Exhaust

All kitchens shall be air conditioned. The exhaust requirements shall be determined by the cooking exhaust hoods within the facility. The kitchen exhaust system shall be designed in accordance with 3.5.6 Food and Beverage Tenant Equipment.

11.23.8 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent.

11.23.9 Filtration

Outside air should be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13 and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

11.23.10 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.23.11 Central Utility Plant

Chilled water and hot water shall be supplied from the CUP. Secondary pumping shall not be used for these facilities.

11.23.12 Plumbing Requirements

All plumbing systems shall conform to the requirements of the IPC as adopted and modified by the CCD building code.

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters.

11.23.13 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of NFPA Standards and CCD building codes. The following description of fire protection requirements is based on NFPA.

A. Provide a wet-pipe sprinkler system for this area.
B. Provide a Class III standpipe system with fire department valve and extinguishers.
C. Provide an automatic detection system, with audible alarms in each room.
D. Provide local and remote annunciation.
E. Provide an extinguisher at each station in the enclosed areas.
F. Single facilities larger than 1500 Square feet require fire sprinkler and fire alarm systems per the requirements of Denver Fire Prevention Bureau, FM Global, and NFPA.

G. Provide manual pull type fire alarm stations at exits and stairwells.
H. All escalator and stair opening perimeters shall be protected.
I. Provide ventilation pressurization and smoke control system for high-rise buildings.

11.24 Structured Parking

11.24.1 Ventilation Systems

Areas enclosed with little exposure to outside, shall be ventilated with constant volume fans. Each unit shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected minimize noise. Supply fans will require a throwaway filter section.

The ductwork system shall consist of a main trunk duct with exhaust registers. The system shall be sized to exhaust a minimum of 500 CFM per parking space in accordance with Industrial Ventilation, A Manual of Recommended Practice, latest edition.

11.24.2 Filtration

The exhaust air shall be filtered before entering the exhaust fan. The dry-type filter media shall have a 2" filter section with a minimum MERV 7 rating per ASHRAE.

11.24.3 Exhaust Fan Controls

The exhaust fans shall be controlled by a remote automation system.

Control Functions:

A. Equipment start/stop with equipment status.
B. Fan failure alarm.
C. Provide CO monitors to control fan operation.

11.24.4 Plumbing Requirements

All plumbing systems shall conform to the requirements of the building code for the CCD.

The floor drainage system shall be designed for the discharge rate of the fire protection system.

The following is a partial list of plumbing fixtures required for this area:

A. Floor drains and cleanouts
B. Sand traps and oil separators

11.24.5 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of NFPA Standards and CCD building codes. The following description of fire protection requirements is based on NFPA.

A. Provide a dry-pipe sprinkler system for this area.
B. Provide a Class I dry-pipe, standpipe system.
C. Single facilities larger than 1,500 square feet require fire sprinkler and fire alarm systems per the requirements of Denver Fire Prevention Bureau, FM Global, and NFPA.
D. On Levels 1, 2, and the part of Level 3 where there are no alternate baggage conveyors the dry pipe systems extends 75' from entrance doors. On Level 4, the dry pipe systems extend throughout the driving lanes in front of the doors. On Level 5, the dry systems cover the entire covered area. All covered drive lanes on all structures have either dry systems or heated blind spaces with dry pendent heads, exception is the passage.

11.25 Parking Toll Plaza

11.25.1 Design Conditions

A. Summer: 75°F (No Humidity Control)

B. Winter: 70°F (No Humidity Control)

11.25.2 Air Handling Systems

This facility shall be air conditioned with a single zone system. Each unit shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected for sound control. In addition, systems shall contain DX cooling system, a throwaway filter section, and a mixed air plenum for outside air and return air duct damper connections. Heat pump units should be considered if gas is not available.

11.25.3 Outdoor Air Requirements

Outside air shall be brought in through the AHU. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.25.4 Toilet Exhaust

The ventilation rate for all toilet room facilities shall be 0.5 CFM per square foot of floor area or as required by the latest edition of ASHRAE 62.1, whichever is more stringent.

11.25.5 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent.

11.25.6 Filtration

Filters with 4" dry type pre-filter section having a minimum rating of MERV 10 shall be provided.

11.25.7 AHU Controls

The AHUs shall be controlled by a space thermostat. The outside air damper shall be opened when the supply fan is running and closed when it is off.

Provide control logic to permit the following:

A. Position outside air dampers and return air dampers. The outside air and exhaust air dampers shall be normally closed, and the return air dampers shall be normally open.

B. Monitor space temperatures.

C. Equipment start/stop.

11.25.8 Plumbing Requirements

All plumbing systems shall conform to the requirements of the IPC as adopted and modified by the CCD building code. Refer to for plumbing design parameters. The following is a partial list of plumbing fixtures required for this area:

A. Lavatories- wall hung or counter mounted.

B. Water closets

C. Stop valves- provided on all fixtures including water coolers.

D. Floor drains and cleanouts.

E. Water coolers

11.25.9 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of NFPA Standards.

A. Provide an extinguisher in the area.

11.26 Office Building

11.26.1 Design Conditions

A. Summer: 75°F (No Humidity Control). Note that XO-123 requires City occupied spaces have to have a VAV cooling setpoint at 78°F.

B. Winter: 70°F

11.26.2 Air Handling Systems

These areas shall be air conditioned with VAV systems. Each unit shall consist of a centrifugal, non-overloading supply air fan selected for sound control. In addition, systems shall contain cooling and heating coil sections (includes cooling only units), an electronic air filter section (Cosa-Tron or equal), if required, a throwaway dry-type filter section, and a mixed air plenum for outside air and return air duct damper connections.

Refer to 3.0.1 Air Handling Systems for air handling system requirements.

The supply air ductwork system shall consist of low-pressure ductwork with variable volume terminal boxes. The system shall be sized to supply a maximum of 1.25 CFM per square foot. Return air shall be through ceiling plenums where practical.

11.26.3 Perimeter Systems

All perimeter glass walls shall be conditioned by a forced air perimeter system. This system shall be variable volume heating and cooling. Utilize sill diffusers to counteract downdrafts during cold weather. Perimeter finned tubed heating systems are an acceptable alternative.

11.26.4 Computer Rooms

Computer rooms, which require year-round cooling, shall be connected to the CUP chilled water system for summer cooling and/or provide a DX cooling system for winter operation, if required by the DEN Mechanical Engineer. The system shall have factory installed and wired controls for chilled water cooling coils, heating coils, dehumidification, and humidification. The unit shall have an electric, steam generating humidifier with controls to limit space humidity. Design conditions shall be:

A. Summer: 68°F, 65% RH max

B. Winter: 68°F

C. Maintain positive space pressure for dust control.

In remote areas where chilled water is not available, the computer room unit shall have a dedicated, dual circuit refrigeration system with remote condensing units located on the roof and electric reheat coils.

11.26.5 Air Curtains

Air curtains shall be provided for use on all main entrances. Overhead fan-coil units shall be used at each entrance.

11.26.6 Outdoor Air Requirements

Outside air shall be brought in through the AHUs.

Refer to 3.2 Ventilation Systems for ventilation requirements.

11.26.7 Toilet Exhaust

The ventilation rate for all toilet room facilities shall be 0.5 CFM per square foot of floor area or as required by the latest edition of ASHRAE 62.1, whichever is more stringent.

11.26.8 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent.

11.26.9 Filtration

Air should be brought in at the roof or penthouse level wherever possible in an attempt to use the highest quality air available. As a minimum, outside air is to be filtered using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13 and a 12" filter section for future removable mixed media.

11.26.10 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.26.11 Plumbing Requirements

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters.

The following is a partial list of plumbing fixtures required for this area:

A. Lavatories- wall hung or counter mounted.
B. Lavatories for the physically disabled- wall hung or counter mounted with offset grid drain for wheelchairs.
C. Water closets, standard and handicap, shall be a blow out type.
D. Stop valves- provided on all fixtures including water coolers.
E. Urinals.
F. Floor drains and cleanouts.
G. All water coolers in public areas shall be barrier free bi-level type.

All domestic water connections, to mechanical systems, including lawn sprinkling systems, shall be protected from backflow.

11.26.12 Central Utility Plant

Chilled water and hot water shall be provided from the CUP. A secondary chilled water and hot water pipe loop shall be provided. Offices remote from the CUP shall have their own central chilled water system and hot water boiler.

11.26.13 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of NFPA Standards and the building code of the CCD. The following description of fire protection requirements is based on NFPA.

A. Provide a wet-pipe sprinkler system for this area.
B. Provide Class I standpipe system.
C. Provide an extinguisher at each station in the enclosed areas.
D. Provide manual pull type fire alarm stations at exits.
E. Single facilities larger than 1,500 square feet require fire sprinkler and fire alarm systems per the requirements of Denver Fire Prevention Bureau, FM Global, and NFPA.

F. All escalator and stair opening perimeters shall be provided with closely spaced sprinkler heads providing a water curtain.

11.26.14 Smoke Control

All elevator and refuge areas shall be served by a separate smoke control system. Refer to the Life Safety DSM for requirements.

11.27 Central Utility Plant Facilities

11.27.1 Design Conditions

A. Summer: Ventilation only in plant area, 75°F in control room, lunch and locker rooms, offices, etc.
B. Winter: 65°F in plant, 70°F in control room, lunch and locker rooms, offices, etc.

11.27.2 Office/Control Room Systems

The office, control room, lunchroom, and locker room areas shall be air conditioned with single zone systems.

Each unit shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected for sound control. In addition, systems shall contain cooling and heating coils, a throwaway filter section, and a mixed air plenum for outside air and return air duct damper connections. Refer to 3.0.1 Air Handling Systems for air handling system requirements. Ductwork shall be for low-pressure system.

11.27.3 Plant/Shop System

The main CUP areas shall be heated and ventilated only. Provide exhaust fans in the main mechanical equipment areas during the cooling season. Exhaust fans shall be centrifugal, or prop type, non-overloading with fan speeds selected for increased life and sound control. Makeup air for exhaust system shall be introduced through an AHU with a filter, control damper, heating section, and louver plenum. The outside air shall be filtered with dry-type filter media with a minimum MERV 7 rating per ASHRAE. The exhaust system shall de designed to provide the minimum ventilation rate during the periods cooling is not required.

11.27.4 Heating System

The main mechanical equipment areas shall be heated with hot water unit heaters.

11.27.5 Outdoor Air Requirements

Outside air for the conditioned spaces shall be brought in through the AHUs and makeup air units. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.27.6 Toilet Exhaust

The minimum ventilation rate for all toilet room facilities is 0.5 CFM per square foot of floor area and 1.0 CFM per square foot of locker area or as required by the latest edition of ASHRAE 62.1, whichever is more stringent.

11.27.7 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. Recommended average outside air ventilation rates shall be as follows:

A. Plant areas: 3 Air changes per hour (winter) minimum, 12 Air changes per hour (summer) minimum
B. Utility Tunnel: 2 ACH continuous operation

11.27.8 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.27.9 Plumbing Requirements

Refer to Chapter 8- Plumbing Requirements. The following is a partial list of plumbing fixtures required:

A. Lavatory faucets
B. Lavatories
C. Lavatories for the physically disabled
D. Water closets
E. Stop valves provided on all fixtures
F. Urinals
G. Floor drains and cleanouts
H. Showers
I. Sand traps and oil separators
J. Water Coolers
K. Sinks

All domestic water connections, to mechanical systems, shall be protected from backflow.

11.27.10 Fire Protection

The fire protection system shall include the following:

A. Provide wet pipe sprinkler system.
B. Provide a Class I standpipe system with extinguisher at each station in the enclosed areas.
C. Provide manual pull type fire alarm station at exits.
D. Single facilities larger than 1,500 square feet require fire sprinkler and fire alarm systems per the requirements of Denver Fire Prevention Bureau, FM Global, and NFPA.

11.27.11 Smoke Control

No smoke control is required for this area.

11.28 Maintenance Facility

11.28.1 Design Conditions

A. Summer: Conditioned Spaces
75°F Shop Areas - Vent only
B. Winter: Conditioned Spaces 70°F
Shop Areas - 70°F

11.28.2 Conditioned Systems

The office and break room area shall be air conditioned with a single zone system.

Each unit shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected for sound control. In addition, systems shall contain cooling and heating coils, a throwaway filter section, and a mixed air plenum for outside air and return air duct damper connections. Refer to 3.0.1 Air Handling Systems for air handling system requirements.

For small, single office areas that might be air-conditioned: Thru-the-wall packaged units may be used in lieu of AHU systems.

Provide a low-pressure ductwork system.

11.28.3 Shop System

The main shop areas shall be heated and ventilated only. Provide exhaust fans in the main mechanical equipment areas during the cooling season. Exhaust fans shall be centrifugal, or prop type, non-overloading with fan speeds selected for extended life and sound control. Makeup air for exhaust system shall be introduced through an AHU with a filter, control damper, and louver plenum. The outside air shall be filtered with dry-type filter media with a minimum MERV 7 rating per ASHRAE. The exhaust system shall de designed to provide the minimum ventilation rate during the periods cooling is not required.

11.28.4 Outdoor Air Requirements

Outside air for the conditioned spaces shall be brought in through the AHU or makeup air unit. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.28.5 Toilet Exhaust

The ventilation rate for all toilet room facilities shall be 0.5 CFM per square foot of floor area or as required by the latest edition of ASHRAE 62.1, whichever is more stringent.

11.28.6 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent.

11.28.7 Filtration

Filters with 4" dry type pre-filter section having a minimum rating of MERV 10 shall be provided.

11.28.8 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.28.9 Plumbing Requirements

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters. The following is a partial list of plumbing fixtures required:

A. Lavatory faucets
B. Lavatories
C. Lavatories for the physically disabled
D. Water closets
E. Stop valves provided on all fixtures
F. Urinals
G. Floor drains and cleanouts
H. Showers
I. Sand traps and oil separators
J. Water Coolers
K. Sinks

All domestic water connections, to mechanical systems, shall be protected from backflow.

Plumbing piping that is either new or existing shall not run through an electrical room. Relocate existing piping to avoid the electrical room.

11.28.10 Fire Protection

The fire protection system shall be as follows:

A. Provide a wet-pipe sprinkler system for larger maintenance facilities (over 20,000 sq. ft.).
B. Provide a dry-pipe system in areas subject to freezing conditions. Refer to the Life Safety DSM for fire protection requirements.
C. Single facilities larger than 1,500 square feet require fire sprinkler and fire alarm systems per the requirements of Denver Fire Prevention Bureau, FM Global, and NFPA.

11.28.11 Smoke Control

No smoke control is required for this area.

11.28.12 Evaporative Cooling

Where the four-pipe distribution system is unavailable and acceptable air quality is available, total evaporative cooling may be utilized (no back-up refrigeration unit) in lieu of refrigeration for offices and for added comfort in frequently used and populated shop areas. Evaporative cooling should be the indirect/direct method of operation. By acceptable air quality, the air must be free of jet fuel exhaust fumes. The indirect/direct method of evaporative cooling uses both indirect and direct evaporative cooling methods to produce cool, conditioned supply air.

11.29 Air Cargo Facility

11.29.1 Design Conditions

A. Summer: Conditioned Spaces
75 °F Shop Areas - Vent only
B. Winter: Conditioned Spaces 70°F
Shop Areas - 70°F

11.29.2 Conditioned Systems

The office and break room area shall be air conditioned with a single zone system.

Each unit shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected for sound control. In addition, systems shall contain cooling and heating coils, a throwaway filter section, and a mixed air plenum for outside air and return air duct damper connections. Refer to 3.0.1 Air Handling Systems for air handling system requirements.

Provide a low-pressure ductwork system.

11.29.3 Warehouse System

The main storage areas shall be heated and ventilated only. Provide exhaust fans for ventilation during the cooling season. Exhaust fans shall be centrifugal, or prop type, non-overloading with fan speeds selected for increased life and sound control. Makeup air for exhaust system shall be introduced through an AHU with a filter, control damper, and louver plenum. The outside air shall be filtered with dry-type filter media with a minimum MERV 7 rating per ASHRAE. The exhaust system shall de designed to provide the minimum ventilation rate during the periods cooling is not required.

11.29.4 Air Curtains

Air curtains shall be provided for use on all main service entrances. Overhead fan-coil units shall be used at each entrance. These units should be indirect gas fired.

11.29.5 Outdoor Air Requirements

Outside air for the conditioned spaces shall be brought in through the AHU and makeup air unit. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.29.6 Toilet Exhaust

The ventilation rate for all toilet room facilities shall be 0.5 CFM per square foot of floor area or as required by the latest edition of ASHRAE 62.1, whichever is more stringent.

11.29.7 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent.

11.29.8 Filtration

Filters with 4" dry type pre-filter section having a minimum rating of MERV 10 shall be provided.

11.29.9 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.29.10 Plumbing Requirements

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters. The following is a partial list of plumbing fixtures required:

A. Lavatory faucets
B. Lavatories
C. Lavatories for the physically disabled
D. Water closets
E. Stop valves provided on all fixtures
F. Urinals
G. Floor drains and cleanouts
H. Showers
I. Sand traps and oil separators
J. Water Coolers
K. Sinks

All domestic water connections, to mechanical systems, shall be protected from backflow.

Plumbing piping that is either new or existing shall not run through an electrical room. Relocate existing piping to avoid the electrical room.

11.29.11 Fire Protection

The fire protection system shall be as follows:

A. Provide a wet-pipe sprinkler system that will be designed to protect the particular type of usage.

B. Provide a hose station with extinguisher at each station in the enclosed areas, as required.
C. Provide manual pull type fire alarm station as required.
D. Single facilities larger than 1,500 square feet require fire sprinkler and fire alarm systems per the requirements of Denver Fire Prevention Bureau, FM Global, and NFPA.

Refer to the Life Safety DSM for fire protection requirements.

11.29.12 Smoke Control

No smoke control is required for this area.

11.30 Aircraft Hanger

11.30.1 Design Conditions

A. Summer: Conditioned spaces:

75°F Shop Areas: Ventilation only or

78°F Hangars: No conditioning required

B. Winter: Conditioned spaces: 70°F

Shop Areas: 70°F

Hangars: 68°F

11.30.2 Ventilation Systems

The office and some shop areas may be air conditioned with a single zone system. Each unit shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected for sound control. In addition, systems shall contain cooling and heating coils, a throwaway filter section, and a mixed air plenum for outside air and return air duct damper connections. Refer to 3.0.1 Air Handling Systems for air handling system requirements.

Provide a low-pressure ductwork system for all normally occupied areas.

Monitor Carbon Monoxide (CO) and Nitrous Oxides (NOx) levels in all hangar spaces. When CO or NOx levels are above safe levels per OSHA and the most recent ASHRAE 90.1 standards for more than five (5) minutes, provide an audible alarm, strobe, and signage in the space. Signs in hangar spaces shall direct occupants to open hangar doors. Inform occupants of unsafe levels being detected.

11.30.3 Shop and Hangar System

The main shop areas shall be heated and ventilated only with unit heaters. Provide exhaust fans for ventilation during the cooling season. Exhaust fans shall be centrifugal, or prop type, non-overloading with fan speeds selected for increased life and sound control. Makeup air for exhaust system shall be introduced through a makeup air unit with a filter, control damper and louver plenum. The outside air shall be filtered with dry-type filter media with a minimum MERV 7 rating per ASHRAE. The exhaust system shall de designed to provide the minimum ventilation rate during the periods cooling is not required.

The hangar area shall be heated and ventilated by one of the following systems:

A. Low intensity vented, gas-fired, infrared system for small hangars, not over 30' high.
B. High-bay unit heaters for large hangars.
C. Air rotation system, utilizing air-handling units that circulate air through the high-bay and back to the low-level air handlers.

Provide ventilation at all hangar low points (e.g., wheel pits, etc.).

11.30.4 Outdoor Air Requirements

Outside air shall be brought in through the air handling or makeup air units. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.30.5 Toilet Exhaust

The ventilation rate for all toilet room facilities shall be 0.5 CFM per square foot of floor area or as required by the latest edition of ASHRAE 62.1, whichever is more stringent.

11.30.6 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. Recommended average outside air ventilation rates shall be as follows:

A. Shop Areas: 4 Air changes/hour (minimum)
B. Hangar Areas: Depends on function

NOTE: These values shall be based on ventilation or exhaust requirements depending on usage or operations in the space.

Special ventilation and filtration will be required if painting will be done in the shops or hangar.

11.30.7 Filtration

Filters with 4" dry type pre-filter section having a minimum rating of MERV 10 shall be provided.

11.30.8 Controls

11.30.8.1 AHUs

A. Off-peak setback of ventilation
B. Cooling coil controls
C. Heating coil controls with preheat where required
D. Monitor space and duct temperatures
E. Equipment start/stop with equipment status
F. Optimal start
G. Economizer controls
H. Alarms for failure of the following:
    a. Fan failure
        1. Space temperature out of specification
        2. Smoke detection
        3. Freeze thermostat shutdown

11.30.8.2 Exhaust Fans

A. Position the outside air dampers. The outside air dampers shall be normally closed. When the exhaust fan is running, the outside air damper shall be open. When the exhaust fan is off, the outside air damper shall be closed.
B. Exhaust fan start/stop with equipment status. Exhaust fan start/stop shall be a function of the mechanical equipment room space temperature. Energize the exhaust fans when space temperature is greater than 85°F.

11.30.8.3 Unit Heaters

The unit heaters shall be started and stopped based on space temperature. When the space temperature is lower than 65°F, the unit heaters shall be energized. The control valve on the unit heater shall be modulated based on space temperature.

11.30.8.4 Infrared Heaters

Units shall cycle to maintain space temperature setpoint.

The automation controls system shall be provided with additional slave panels to control the single zone AHU, the exhaust fans, and the unit heaters, as necessary. Tie to the Facilities EMCS.

11.30.9 Plumbing Requirements

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters. The following is a partial list of plumbing fixtures required:

A. Lavatory faucets
B. Lavatories
C. Lavatories for the physically disabled.
D. Water closets
E. Stop valves provided on all fixtures.
F. Urinals
G. Floor drains and cleanouts.
H. Showers
I. Sand traps and oil separators.
J. Water Coolers
K. Sinks

All domestic water connections, to mechanical systems, shall be protected from backflow.

Plumbing piping that is either new or existing shall not run through an electrical room. Relocate existing piping to avoid the electrical room.

11.30.10 Fire Protection

The fire protection system shall be as follows:

A. Provide a foam water deluge system in the hangar, as required by size.
B. Provide a wet-pipe sprinkler system in the shops and offices and smaller hangars.
C. Provide a Class I standpipe system with extinguisher at each station in the enclosed areas.
D. Provide manual pull type fire alarm stations at exits.
E. Evaluate need of fire pumps and water storage tanks. Provide as required.
F. Provide monitor nozzles as required.
G. Single facilities larger than 1,500 square feet require fire sprinkler and fire alarm systems per the requirements of Denver Fire Prevention Bureau, FM Global, and NFPA.
H. Provide all necessary detection and actuation for the above noted systems with appropriate monitoring by the fire alarm system

Refer to the Life Safety DSM for fire protection requirements.

11.30.11 Evaporative Cooling

Where the four-pipe distribution system is unavailable and acceptable air quality is available, total evaporative cooling may be utilized (no back-up refrigeration unit) in lieu of refrigeration for offices and for added comfort in frequently used and populated shop areas. Evaporative cooling should be the indirect/direct method of operation. By acceptable air quality, the air must be free of jet fuel exhaust fumes. The indirect/direct method of evaporative cooling uses both indirect and direct evaporative cooling methods to produce cool, conditioned supply air.

11.31 Flight Kitchen

11.31.1 Design Conditions

A. Summer: 75°F

B. Winter: 70°F

11.31.2 Air Handling Systems

This area shall be air conditioned with a single zone system, constant volume systems. (VAV is an acceptable alternative if it is determined several zones are required.)

Each unit shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected for sound control. In addition, systems shall contain cooling and heating coils (includes cooling only units), a throwaway filter section and a mixed air plenum for outside air and return air duct damper connections. Refer to 3.0.1 Air Handling Systems for air handling system requirements.

11.31.3 Outdoor Air Requirements

Outside air shall be brought in through the AHU. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.31.4 Toilet Exhaust

The ventilation rate for all toilet room facilities shall be 0.5 CFM per square foot of floor area or as required by the latest edition of ASHRAE 62.1, whichever is more stringent.

11.31.5 Kitchen Exhaust

All kitchens shall be air conditioned. The exhaust requirements shall be determined by the cooking and exhaust hoods installed within the facility. The kitchen exhaust system shall be designed in accordance with 3.5.6 Food and Beverage Tenant Equipment.

11.31.6 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent.

11.31.7 Filtration

Filters with 4" dry type pre-filter section having a minimum rating of MERV 10 shall be provided.

11.31.8 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.31.9 Plumbing Requirements

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters. The following is a partial list of plumbing fixtures required for this facility:

A. Lavatory faucets- provided with flow restriction.
B. Lavatories- wall hung or counter mounted.
C. Lavatories for the physically disabled- wall hung or counter mounted with offset grid drain for wheelchairs.
D. Water closets, standard and handicap- blow out type.
E. Stop valves- provided on all fixtures.
F. Urinals
G. Floor drains and cleanouts.
H. Water coolers- barrier free bilevel type.
I. Sand traps and oil separators.
J. Water Coolers
K. Sinks
L. Hot water heaters

All domestic water connections, to mechanical systems, including lawn sprinkling systems, shall be protected from backflow.

Plumbing piping that is either new or existing shall not run through an electrical room. Relocate existing piping to avoid the electrical room.

11.31.10 Fire Protection

The fire protection system shall be as follows:

A. Provide a wet-pipe sprinkler system for this area.
B. Provide a pre-engineered carbon dioxide extinguishing system for the kitchen exhaust hoods in accordance with NFPA 12, Standard on Carbon Dioxide Extinguishing Systems. The system shall be capable of automatic detection with local or remote manual actuation. Accessories shall be installed for mechanical or electrical gas line shut-off applications. System shall be listed with Underwriters Laboratories, Inc.
C. Single facilities larger than 1,500 square feet require fire sprinkler and fire alarm systems per the requirements of Denver Fire Prevention Bureau, FM Global, and NFPA.

Refer to the Life Safety DSM for fire protection requirements.

11.32 Snow Removal Equipment Facility

11.32.1 Design Conditions

A. Summer: Conditioned Spaces

   75°F Shop Areas: Vent only

B. Winter: Conditioned Spaces 70°F

   Shop Areas: 70°F

11.32.2 Conditioned Systems

The office and break room area shall be air conditioned with a single zone system.

Each unit shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected for sound control. In addition, systems shall contain cooling and heating coils, a throwaway filter section, and a mixed air plenum for outside air and return air duct damper connections. Refer to 3.0.1 Air Handling Systems for air handling system requirements.

For small, single office areas that might be air-conditioned: Thru-the-wall packaged units may be used in lieu of AHU systems.

Provide a low-pressure ductwork system.

11.32.3 Shop System

The main shop areas shall be heated and ventilated only. Provide exhaust fans in the main mechanical equipment areas during the cooling season. Exhaust fans shall be centrifugal, or prop type, non-overloading with fan speeds selected for extended life and sound control. Makeup air for exhaust system shall be introduced through an AHU with a filter, control damper, and louver plenum. The outside air shall be filtered with dry-type filter media with a minimum MERV 7 rating per ASHRAE. The exhaust system shall be designed to provide the minimum ventilation rate during the periods cooling is not required.

Low intensity infrared heating may be used in the equipment bays as an alternative heating method.

11.32.4 Outdoor Air Requirements

Outside air for the conditioned spaces shall be brought in through the AHU or makeup air unit. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.32.5 Toilet Exhaust

The ventilation rate for all toilet room facilities shall be 0.5 CFM per square foot of floor area or as required by the latest edition of ASHRAE 62.1, whichever is more stringent.

11.32.6 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent.

11.32.7 Filtration

Filters with 4" dry type pre-filter section having a minimum rating of MERV 10 shall be provided.

11.32.8 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.32.9 Plumbing Requirements

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters. The following is a partial list of plumbing fixtures required:

A. Lavatory faucets
B. Lavatories
C. Lavatories for the physically disabled
D. Water closets
E. Stop valves provided on all fixtures
F. Urinals
G. Floor drains and cleanouts
H. Showers
I. Sand traps and oil separators
J. Water Coolers
K. Sinks

All domestic water connections, to mechanical systems, shall be protected from backflow.

Plumbing piping that is either new or existing shall not run through an electrical room. Relocate existing piping to avoid the electrical room.

11.32.10 Fire Protection

The fire protection system shall be as follows:

A. Provide fire hose stations with carbon dioxide extinguisher in cabinets throughout the area.
B. Single facilities larger than 1,500 square feet require fire sprinkler and fire alarm systems per the requirements of Denver Fire Prevention Bureau, FM Global, and NFPA.

Refer to the Life Safety DSM for fire protection requirements.

11.32.11 Evaporative Cooling:

Where the four-pipe distribution system is unavailable and acceptable air quality is available, total evaporative cooling may be utilized (no back-up refrigeration unit) in lieu of refrigeration for offices and for added comfort in frequently used and populated shop areas. Evaporative cooling should be the indirect/direct method of operation. By acceptable air quality, the air must be free of jet fuel exhaust fumes. The indirect/direct method of evaporative cooling uses both indirect and direct evaporative cooling methods to produce cool, conditioned supply air.

11.33 Fire Crash Rescue Facility

11.33.1 Design Conditions

A. Summer: Conditioned Spaces 75°F

   Shop Areas: Vent Only

B. Winter: Conditioned Spaces 70°F

   Shop Areas: 70°F

11.33.2 Conditioned Systems

The Aircraft Rescue and Firefighting (ARFF) office and break room area shall be air conditioned with a single zone system.

Each unit shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected for sound control. In addition, systems shall contain cooling and heating coils, a throwaway filter section, and a mixed air plenum for outside air and return air duct damper connections. Refer to 3.0.1 Air Handling Systems for air handling system requirements.

For small, single office areas or sleeping/residential type areas that might be air-conditioned: Thru-the-wall packaged units may be used in lieu of AHU systems.

Provide a low-pressure ductwork system.

11.33.3 Vehicle/Maintenance Systems

The main shop areas shall be heating and ventilated only. Provide exhaust fans in the main mechanical equipment areas during the cooling season. Exhaust fans shall be centrifugal, or prop type, non-overloading with fan speeds selected for extended life and sound control. Makeup air for exhaust system shall be introduced through an AHU with a filter, control damper, and louver plenum. The outside air shall be filtered with dry-type filter media with a minimum MERV 7 rating per ASHRAE. The exhaust system shall be designed to provide the minimum ventilation rate during the periods cooling is not required.

11.33.4 Outdoor Air Requirements

Outside air for the conditioned spaces shall be brought in through the AHU or makeup air unit. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.33.5 Toilet Exhaust

The minimum ventilation rate for all toilet room facilities shall be 0.5 CFM per square foot of floor area or as required by the latest edition of ASHRAE 62.1, whichever is more stringent.

11.33.6 Kitchen Exhaust

All kitchens shall be air conditioned. The exhaust requirements shall be determined by the cooking and exhaust hoods installed within the facility. The kitchen exhaust system shall be designed in accordance with 3.5.6 Food and Beverage Tenant Equipment.

11.33.7 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent.

11.33.8 Filtration

Filters with 4" dry type pre-filter section having a minimum rating of MERV 10 shall be provided.

11.33.9 Controls

Refer to 5.2 Sample Control Components and Requirements.

11.33.10 Plumbing Requirements

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters. The following is a partial list of required plumbing fixtures:

A. Lavatory faucets
B. Lavatories
C. Lavatories for the physically disabled
D. Water closets
E. Stop valves provided on all fixtures
F. Urinals
G. Floor drains and cleanouts
H. Showers
I. Sand traps and oil separators
J. Water coolers
K. Sinks

All domestic water connections, to mechanical systems, shall be protected from backflow.

Plumbing piping that is either new or existing shall not run through an electrical room. Relocate existing piping to avoid the electrical room.

11.33.11 Fire Protection

The fire protection system shall be as follows:

A. Provide fire extinguishers in cabinets throughout the area.
B. Single facilities larger than 1,500 square feet require fire sprinkler and fire alarm systems per the requirements of Denver Fire Prevention Bureau, FM Global, and NFPA.

Refer to the Life Safety DSM for fire protection requirements.

11.33.12 Evaporative Cooling

Where the four-pipe distribution system is unavailable and acceptable air quality is available, total evaporative cooling may be utilized (no back-up refrigeration unit) in lieu of refrigeration for offices and for added comfort in frequently used and populated shop areas. Evaporative cooling should be the indirect/direct method of operation. By acceptable air quality, the air must be free of jet fuel exhaust fumes. The indirect/direct method of evaporative cooling uses both indirect and direct evaporative cooling methods to produce cool, conditioned supply air.

11.34 Rental Car Support Facility

11.34.1 Design Conditions

A. Summer: Conditioned Spaces 75°F

   Shop Areas: Vent Only

B. Winter: Conditioned Spaces 70°F

   Shop Areas: 70°F

11.34.2 Ventilation Systems

The office and break room area shall be air conditioned with a single zone system.

Each unit shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected for sound control. In addition, systems shall contain cooling and heating coils, a throwaway filter section, and a mixed air plenum for outside air and return air duct damper connections. Refer to 3.0.1 Air Handling Systems for air handling system requirements.

For small, single office areas that might be air-conditioned: Thru-the-wall packaged units may be used in lieu of AHU systems.

Provide a low-pressure ductwork system.

11.34.3 Maintenance/Shop System

The main plant areas shall be heating and ventilated only. Provide exhaust fans in the main mechanical equipment areas during the cooling season. Exhaust fans shall be centrifugal, or prop type, non-overloading with fan speeds selected for extended life and sound control. Makeup air for exhaust system shall be introduced through an AHU with a filter, control damper and louver plenum. The outside air shall be filtered with dry-type filter media with a minimum MERV 7 rating per ASHRAE. The exhaust system shall be designed to provide the minimum ventilation rate during the periods cooling is not required.

11.34.4 Outdoor Air Requirements

Outside air for the conditioned spaces shall be brought in through the AHU or makeup air unit. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.34.5 Toilet Exhaust

The minimum ventilation rate for all toilet room facilities shall be 0.5 CFM per square foot of floor area or as required by the latest edition of ASHRAE 62.1, whichever is more stringent.

11.34.6 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent.

11.34.7 Filtration

Filters with 4" dry type pre-filter section having a minimum rating of MERV 10 shall be provided.

11.34.8 Controls

Refer to 5.2 Sample Control Components and Requirements.

11.34.9 Plumbing Requirements

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters. The following is a partial list of required plumbing fixtures:

A. Lavatory faucets
B. Lavatories
C. Lavatories for the physically disabled
D. Water closets
E. Stop valves provided on all fixtures
F. Urinals
G. Floor drains and cleanouts
H. Showers
I. Sand traps and oil separators
J. Water coolers
K. Sinks

All domestic water connections, to mechanical systems, shall be protected from backflow.

Plumbing piping that is either new or existing shall not run through an electrical room. Relocate existing piping to avoid the electrical room.

11.34.10 Fire Protection

The fire protection system shall be as follows:

A. Provide a dry-pipe sprinkler system for unheated areas.
B. Provide fire hose station (as required) with carbon dioxide extinguisher in cabinets throughout the area.
C. Single facilities larger than 1,500 square feet require fire sprinkler and fire alarm systems per the requirements of Denver Fire Prevention Bureau, FM Global, and NFPA.

Refer to the Life Safety DSM for fire protection requirements.

11.34.11 Evaporative Cooling

Where the four-pipe distribution system is unavailable and acceptable air quality is available, total evaporative cooling may be utilized (no back-up refrigeration unit) in lieu of refrigeration for offices and for added comfort in frequently used and populated shop areas. Evaporative cooling should be the indirect/direct method of operation. By acceptable air quality, the air must be free of jet fuel exhaust fumes. The indirect/direct method of evaporative cooling uses both indirect and direct evaporative cooling methods to produce cool, conditioned supply air.

11.35 Auto Service Station

11.35.1 Design Conditions

A. Summer: Conditioned Spaces 75°F

Shop Areas: Vent Only

B. Winter: Conditioned Spaces 70°F

Shop Areas: 70°F

11.35.2 Conditioned Systems

The office and break room area shall be air conditioned with a single zone system.

Each unit shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected for sound control. In addition, systems shall contain cooling and heating coils, a throwaway filter section, and a mixed air plenum for outside air and return air duct damper connections. Refer to 3.0.1 Air Handling Systems for air handling system requirements.

For small, single office areas that might be air-conditioned: Thru-the-wall packaged units may be used in lieu of AHU systems.

Provide a low-pressure ductwork system.

11.35.3 Shop System

The main shop areas shall be heating and ventilated only. Provide exhaust fans in the main mechanical equipment areas during the cooling season. Exhaust fans shall be centrifugal, or prop type, non-overloading with fan speeds selected for extended life and sound control. Makeup air for exhaust system shall be introduced through an AHU with a filter, control damper, and louver plenum. The outside air shall be filtered with dry-type filter media with a minimum MERV 7 rating per ASHRAE. The exhaust system shall be designed to provide the minimum ventilation rate during the periods cooling is not required.

11.35.4 Outdoor Air Requirements

Outside air for the conditioned spaces shall be brought in through the AHU or makeup air unit. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.35.5 Toilet Exhaust

The minimum ventilation rate for all toilet room facilities shall be 0.5 CFM per square foot of floor area or as required by the latest edition of ASHRAE 62.1, whichever is more stringent.

11.35.6 Automobile Exhaust System

The maintenance area shall be equipped with a constant volume exhaust system. The system shall consist of a centrifugal, non-overloading, exhaust fan with fan speeds selected for sound control and equipment life.

The ductwork system shall consist of a main trunk duct with flexible duct take-offs for connection to the vehicles exhaust tailpipes. Provisions shall be made for vehicles with both single and dual exhaust systems. The system shall be sized to exhaust a minimum of 100 CFM per vehicle with an engine horsepower less than 200 HP and 200 CFM per vehicle with an engine horsepower greater than 200 HP. The design shall comply with Industrial Ventilation, A Manual of Recommended Practice, latest edition.

11.35.7 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent.

11.35.8 Filtration

Filters with 4" dry type pre-filter section having a minimum rating of MERV 10 shall be provided.

11.35.9 Controls

Refer to 5.2 Sample Control Components and Requirements.

11.35.10 Plumbing Requirements

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters. The following is a partial list of required plumbing fixtures:

A. Lavatory faucets
B. Lavatories
C. Lavatories for the physically disabled
D. Water closets
E. Stop valves provided on all fixtures
F. Urinals
G. Floor drains and cleanouts
H. Showers
I. Sand traps and oil separators
J. Water coolers
K. Sinks

All domestic water connections, to mechanical systems, shall be protected from backflow.

Plumbing piping that is either new or existing shall not run through an electrical room. Relocate existing piping to avoid the electrical room.

11.35.11 Fire Protection

The fire protection system shall be provided as follows:

A. Provide fire hose station with carbon dioxide extinguisher in cabinets throughout the area.
B. Single facilities larger than 1,500 square feet require fire sprinkler and fire alarm systems per the requirements of Denver Fire Prevention Bureau, FM Global, and NFPA.

Refer to the Life Safety DSM for fire protection requirements.

11.35.12 Evaporative Cooling

Where the four-pipe distribution system is unavailable and acceptable air quality is available, total evaporative cooling may be utilized (no back-up refrigeration unit) with an indirect/direct method of operation.

11.36 Aircraft Fueling Control Facility

11.36.1 Design Conditions

A. Summer: Conditioned Spaces 75°F

Shop Areas: Vent Only

B. Winter: Conditioned Spaces 70°F

Shop Areas: 70°F

11.36.2 Conditioned Systems

The office and break room area shall be air conditioned with a single zone system.

Each unit shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected for sound control. In addition, systems shall contain cooling and heating coils, a throwaway filter section, and a mixed air plenum for outside air and return air duct damper connections. Refer to 3.0.1 Air Handling Systems for air handling system requirements.

For small, single office areas that might be air-conditioned: Thru-the-wall packaged units may be used in lieu of AHU systems.

Provide a low-pressure ductwork system.

11.36.3 Maintenance/Shop System

The main shop areas shall be heating and ventilated only. Provide exhaust fans in the main mechanical equipment areas during the cooling season. Exhaust fans shall be centrifugal, or prop type, non-overloading with fan speeds selected for extended life and sound control. Makeup air for exhaust system shall be introduced through an AHU with a filter, control damper, and louver plenum. The outside air shall be filtered with dry-type filter media with a minimum MERV 7 rating per ASHRAE. The exhaust system shall be designed to provide the minimum ventilation rate during the periods cooling is not required.

11.36.4 Outdoor Air Requirements

Outside air for the conditioned spaces shall be brought in through the AHU or makeup air unit. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.36.5 Toilet Exhaust

The minimum ventilation rate for all toilet room facilities shall be 0.5 CFM per square foot of floor area or as required by the latest edition of ASHRAE 62.1, whichever is more stringent.

11.36.6 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent.

11.36.7 Vehicle Exhaust System

The maintenance area shall be equipped with a constant volume exhaust system. The system shall consist of a centrifugal, non-overloading, exhaust fan with fan speeds selected for sound control and equipment life.

The ductwork system shall consist of a main trunk duct with flexible duct take-offs for connection to the vehicles exhaust tailpipes. Provisions shall be made for vehicles with both single and dual exhaust systems. The system shall be sized to exhaust a minimum of 100 CFM per vehicle with an engine horsepower less than 200 HP and 200 CFM per vehicle with an engine horsepower greater than 200 HP. The design shall comply with Industrial Ventilation, A Manual of Recommended Practice, latest edition.

11.36.8 Filtration

Filters with 4" dry type pre-filter section having a minimum rating of MERV 10 shall be provided.

11.36.9 Controls

Refer to 5.2 Sample Control Components and Requirements.

11.36.10 Plumbing Requirements

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters. The following is a partial list of required plumbing fixtures:

A. Lavatory faucets
B. Lavatories
C. Lavatories for the physically disabled
D. Water closets
E. Stop valves provided on all fixtures
F. Urinals
G. Floor drains and cleanouts
H. Showers
I. Sand traps and oil separators
J. Water coolers
K. Sinks

All domestic water connections, to mechanical systems, shall be protected from backflow.

Plumbing piping that is either new or existing shall not run through an electrical room. Relocate existing piping to avoid the electrical room.

11.36.11 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of NFPA Standards and local codes. The following description of fire protection requirements is based on NFPA. Local fire and code officials must be contacted to verify their concurrence with the proposed system.

A. Provide an automatic heat detection system for this area.
B. Provide a fire hose station extinguisher at each station in the enclosed areas.
C. Single facilities larger than 1,500 square feet require fire sprinkler and fire alarm systems per the requirements of Denver Fire Prevention Bureau, FM Global, and NFPA.

Refer to the Life Safety DSM for fire protection requirements.

11.36.12 Evaporative Cooling

Where acceptable air quality is available, total evaporative cooling may be utilized (no back-up refrigeration unit) with an indirect/direct method of operation.

11.37 General Aviation Facilities

11.37.1 Design Conditions

A. Summer: Conditioned spaces 75°F

   Shop Areas: Ventilation only or 75°F

   Hangars: No conditioning required

B. Winter: Conditioned spaces 70°F

   Shop Areas: 70°F

Hangars: 68°F

11.37.2 Air Handling Systems

The office and break room area shall be air conditioned with a single zone system.

Each unit shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected for sound control. In addition, systems shall contain cooling and heating coils, a throwaway filter section, and a mixed air plenum for outside air and return air duct damper connections. Refer to 3.0.1 Air Handling Systems for air handling system requirements.

For small, single office areas that might be air-conditioned: Thru-the-wall packaged units may be used in lieu of AHU systems.

Provide a low-pressure ductwork system.

11.37.3 Shop and Hangar System

The main shop areas shall be heated and ventilated only with unit heaters. Provide exhaust fans for ventilation during the cooling season. Exhaust fans shall be centrifugal, or prop type, non-overloading with fan speeds selected for increased life and sound control. Makeup air for exhaust system shall be introduced through a makeup air unit with a filter, control damper, and louver plenum. The outside air shall be filtered with dry-type filter media a minimum MERV 7 rating per ASHRAE. The exhaust system shall be designed to provide the minimum ventilation rate during the periods cooling is not required.

The hangar area shall be heated and ventilated by one of the following systems:

A. Low intensity vented gas-fired, infrared system for small hangars, not over 30' high.
B. High-bay unit heaters for large hangars.
C. Air rotation system utilizing air-handling units that circulate air through the high-bay and back to the low-level air handlers.

Provide ventilation at all hangar low points (e.g., wheel pits, etc.).

11.37.4 Outdoor Air Requirements

Outside air shall be brought in through the air handling or makeup air units. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.37.5 Toilet Exhaust

The minimum ventilation rate for all toilet room facilities shall be 0.5 CFM per square foot of floor area or as required by the latest edition of ASHRAE 62.1, whichever is more stringent.

11.37.6 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. Recommended average outside air ventilation rates shall be as follows:

A. Shop Areas: *4 air changes/hour (minimum)
B. Hangar Areas: *Depends on function

*These values shall be based on ventilation or exhaust requirements depending on usage or operations in the space.

11.37.7 Filtration

Filters with 4" dry type pre-filter section having a minimum rating of MERV 10 shall be provided.

11.37.8 Controls

Refer to 5.2 Sample Control Components and Requirements.

11.37.9 Plumbing Requirements

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters. The following is a partial list of required plumbing fixtures:

A. Lavatory faucets
B. Lavatories
C. Lavatories for the physically disabled
D. Water closets
E. Stop valves provided on all fixtures
F. Urinals
G. Floor drains and cleanouts
H. Showers
I. Sand traps and oil separators
J. Water coolers
K. Sinks

All domestic water connections, to mechanical systems, shall be protected from backflow.

Plumbing piping that is either new or existing shall not run through an electrical room. Relocate existing piping to avoid the electrical room.

11.37.10 Fire Protection

The fire protection system shall be as follows:

A. Single facilities larger than 1,500 square feet require fire sprinkler and fire alarm systems per the requirements of Denver Fire Prevention Bureau, FM Global, and NFPA.
B. Provide a dry-pipe sprinkler system. Wet-pipe acceptable in shops and offices.
C. Provide fire hose stations with extinguisher at each station in the enclosed areas.

Refer to the Life Safety DSM for fire protection requirements.

11.37.11 Evaporative Cooling

Where acceptable air quality is available, total evaporative cooling may be utilized (no back-up refrigeration unit) with an indirect/direct method of operation.

11.38 Communications Center

11.38.1 Design Conditions

A. Summer: 74°F (50% RH Max)
B. Winter: 72°F

11.38.2 Air Handling Systems

This facility shall be air conditioned with a VAV system.

Each unit shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected for sound control. In addition, system shall contain cooling and heating coil sections (includes cooling only units), an electronic air filter section, a throwaway filter section, air blender section to eliminate air stratification, and a mixed air plenum for outside air and return air duct damper connections. Refer to 3.0.1 Air Handling Systems for air handling system requirements.

The supply air ductwork system shall consist of low-pressure ductwork with variable volume terminal boxes. Each VAV box shall have its own controls tied to the FCS. The system shall be sized to supply approximately 1.25 CFM per square foot at maximum flow.

11.38.3 Computer and Electronic Equipment Rooms

Electronic equipment rooms, which require year-round cooling, may be connected to the CUP chilled water system for cooling; in addition, critical computer and/or communications rooms shall have their own DX cooling system for winter operation. The system shall have factory-installed and wired controls for chilled water and DX cooling coils, heating coils, dehumidification, and humidification. The unit shall have an electric, steam generating humidifier with controls to limit space humidity to 60% maximum.

11.38.4 Outdoor Air Requirements

Outside air shall be brought in through the AHUs. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.38.5 Toilet Exhaust

The minimum ventilation rate for all toilet room facilities shall be 0.5 CFM per square foot of floor area or as required by the latest edition of ASHRAE 62.1, whichever is more stringent.

11.38.6 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent.

11.38.7 Filtration

Outside air shall be filtered with dry-type filter media. As a minimum outside air is to be filtered using 12" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13 and a 12".

11.38.8 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.38.9 Plumbing Requirements

Refer to for plumbing design parameters. A partial listing of plumbing fixture requirements is as follows

A. Lavatory faucets with flow restriction devices
B. Lavatories, wall hung or counter mounted.
C. Lavatories for the physically disabled, wall hung or counter mounted with offset grid drain for wheelchairs.
D. Water closets, standard and handicap, a blowout.
E. Stop valves provided on all fixtures.
F. Urinals.
G. Floor drains and cleanouts.

All domestic water connections, to mechanical systems, including lawn-sprinkling systems, shall be protected from backflow.

Plumbing piping that is either new or existing shall not run through the Computer and Electronic Equipment room or any associated electrical rooms. Relocate existing piping to avoid the rooms.

If sloped piping cannot be relocated, a sheet metal gutter under the pipe shall be provided. The gutter system shall be fully designed and detailed on the contract documents. No component of the gutter shall be left to the contractor's discretion. Details shall accommodate the following:

A. Gutters shall be supported independently of the sloped piping.
B. Structural supports and connections to the building structure.
C. Details are to include minimum slope, drain location, sheet metal gauge, and drain connection to the gutter.
D. Dedicated piping from the gutter low points to an open site location. Open site termination shall include signage defining procedures in the event of a leak. Sign shall read, "If water is observed from the pipe below (or above), immediately contact Maintenance Control at (303) 342-2800".
E. Dedicated drain piping to extent to outside of the room and be protected by a secondary gutter.
F. Do not route any drain piping over switchgear, transformers, or other electrical equipment.

Gutter shall not block or inhibit access to surrounding systems.

11.38.10 Fire Protection

The fire protection system shall be provided as follows:

A. Provide a wet-pipe sprinkler system unless prohibited in areas having electronic equipment.
B. Provide an automatic detection system in areas not sprinklered establish and verify any requirements for the areas above dropped ceiling/ceiling plenums require detection systems.
C. Establish with the Denver Fire Prevention Bureau any alternate system types (FM-200).
D. Provide extinguishers in cabinets throughout the area.

Refer to the Life Safety DSM for fire protection requirements.

11.39 Security Guard House

11.39.1 Design Conditions

A. Summer: 75°F
B. Winter: 70°F

11.39.2 Air Handling Systems

This facility shall be air conditioned with a single zone system.

Each unit shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected for sound control. In addition, systems shall contain DX cooling and heating coils, a throwaway filter section, and a mixed air plenum for outside air and return air duct damper connections. Heat pump systems should be considered if natural gas is not available.

11.39.3 Outdoor Air Requirements

Outside air shall be brought in through the AHU. Refer to 3.2 Ventilation Systems for ventilation requirements.

11.39.4 Toilet Exhaust

The ventilation rate for all toilet room facilities shall be 0.5 CFM per square foot of floor area or as required by the latest edition of ASHRAE 62.1, whichever is more stringent.

11.39.5 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent.

11.39.6 Filtration

Filters with 4" dry type pre-filter section having a minimum rating of MERV 10 shall be provided.

11.39.7 Plumbing Requirements

All plumbing systems shall conform to the requirements of the IPC as adopted and modified by the CCD building code. Refer to Chapter 8- Plumbing Requirements for plumbing design parameters.

The following is a partial list of plumbing fixtures required for this area:

A. Lavatories- wall hung or counter mounted.
B. Water closets
C. Stop valves- provided on all fixtures including water coolers.
D. Floor drains and cleanouts.
E. Water coolers

11.39.8 Fire Protection

The fire protection system shall be provided as follows:

A. Provide an extinguisher.

Refer to the Life Safety DSM for fire protection requirements.

11.39.9 AHU Controls

Provide control logic to permit the following:

A. Position outside air dampers and return air dampers. The outside air and exhaust air dampers shall be normally closed, and the return air dampers shall be normally open.
B. Heating and cooling coil controls.
C. Monitor space and duct temperatures.
D. Equipment start/stop with equipment status.
E. Alarms for failure of the following:
    a. Fan failure.
    b. Space temperature out of specification.
    c. Freeze thermostat shutdown.

11.40 Warehouse Facility

11.40.1 Design Conditions

A. Summer: Conditioned spaces 75°F

   Storage Areas: Ventilation only

B. Winter: Conditioned Spaces 70°F

   Storage Areas: 70°F

11.40.2 Conditioned Systems

The office and break room area shall be air conditioned with a single zone system.

Each unit shall consist of a centrifugal, non-overloading supply air fan with fan speeds selected for sound control. In addition, systems shall contain cooling and heating coils, a throwaway filter section, and a mixed air plenum for outside air and return air duct damper connections. Refer to 3.0.1 Air Handling Systems for air handling system requirements.

Provide a low-pressure ductwork system.

11.40.3 Warehouse System

The main storage areas shall be heated and ventilated only. Provide exhaust fans for ventilation during the cooling season. Exhaust fans shall be centrifugal, or prop type, non-overloading with fan speeds selected for increased life and sound control. Makeup air for exhaust system shall be introduced through an AHU with a filter, control damper, and louver plenum. The outside air shall be filtered with dry-type filter media with a minimum MERV 7 rating per ASHRAE. The exhaust system shall be designed to provide the minimum ventilation rate during the periods cooling is not required.

11.40.4 Air Curtains

Air curtains shall be provided for use on all main service entrances. Overhead fan-coil units shall be used at each entrance. These units should be indirect gas fired.

11.40.5 Outdoor Air Requirements

Outside air for the conditioned spaces shall be brought in through the AHU and makeup air unit. Refer to- for ventilation requirements.

11.40.6 Toilet Exhaust

The ventilation rate for all toilet room facilities shall be 0.5 CFM per square foot of floor area or as required by the latest edition of ASHRAE 62.1, whichever is more stringent.

11.40.7 Ventilation Rates

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent.

11.40.8 Filtration

Filters with 4" dry type pre-filter section having a minimum rating of MERV 10 shall be provided.

11.40.9 AHU Controls

Refer to 5.2 Sample Control Components and Requirements.

11.40.10 Plumbing Requirements

Refer to Chapter 8- Plumbing Requirements for plumbing design parameters. The following is a partial list of plumbing fixtures required:

A. Lavatory faucets
B. Lavatories
C. Lavatories for the physically disabled
D. Water closets

E. Stop valves provided on all fixtures
F. Urinals
G. Floor drains and cleanouts
H. Showers
I. Sand traps and oil separators
J. Water Coolers
K. Sinks

All domestic water connections, to mechanical systems, shall be protected from backflow.

Plumbing piping that is either new or existing shall not run through an electrical room. Relocate existing piping to avoid the electrical room.

11.40.11 Fire Protection

The fire protection system shall be as follows:

A. Provide a wet/dry-pipe sprinkler system that shall be designed to protect the particular type of usage including density suitable for anticipated storage type and method.
B. Provide a hose station with extinguisher at each station in the enclosed areas, as required.
C. Provide manual pull type fire alarm station as required.
D. Provide rack storage fire protection system as required or increased overhead densities suitable for the commodities stored.

Refer to the Life Safety DSM for fire protection requirements.

11.41 Bulk Storage Facility (Urea and Sand Storage)

11.41.1 Design Conditions

A. Summer: Vent Only
B. Winter: Vent Only

11.41.2 Ventilation System

The bulk storage facility shall be ventilated to remove dust particles. Provide exhaust fans for ventilation year-round. Exhaust fans shall be centrifugal, or propeller type, non-overloading with fan speeds selected for increased life. Makeup air for exhaust system shall be introduced through a wall-mounted louver with bird screen. Provide unit heaters as required for minimal heating of space.

11.41.3 Ventilation Rate

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. Minimum ventilation rate shall be 2 cfm/ft^2.

11.41.4 Exhaust Fan Controls

Exhaust fan shall operate year-round to provide for the removal of dust particles from the Bulk Storage Facility.

Alarm for failure shall include:

A. Fan failure

11.41.5 Unit Heater Controls

Unit heaters shall operate to maintain space at 50°F. Unit heaters shall be started and stopped based on space temperature. When the space temperature is lower than 50°F, the unit heaters shall be energized.

11.42 Baggage Tunnel

11.42.1 Design Conditions

A. Summer: Vent Only
B. Winter: Vent Only

11.42.2 Ventilation System

The baggage tunnel shall be ventilated to remove products of combustion. Provide exhaust fans for ventilation year-round. Exhaust fans shall be centrifugal, or propeller type, non-overloading with fan speeds selected for increased life. Makeup air for exhaust system shall be introduced through the tunnel ramp openings, which are open to the outside at the apron level.

11.42.3 Ventilation Rate

All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. Minimum ventilation rate shall be 4 ACH per CCD Building and Construction Division.

11.42.4 Exhaust Fan Controls

Exhaust fan shall operate year-round to provide for the removal of products of combustion from the baggage tunnel.

Alarm for failure shall include fan failure.

11.42.5 Smoke Control

All tunnel areas shall be served by a separate smoke control system. Refer to the Life Safety DSM for requirements.

11.43 Utility Tunnel

11.43.1 Design Conditions

A. Summer: No ventilation, relief air only
B. Winter: No ventilation, relief air only

11.43.2 Ventilation System

The Utility Tunnel ventilation is provided by exhaust fans located in the AGTS/Baggage Mechanical and Electrical rooms. The exhaust air fans are ducted to the Concourse roof at every Concourse.

11.43.3 Exhaust Fan Controls

Fans are controlled manually and are intended to operate continuously.

11.43.4 Smoke Control

The Utility Tunnel does not have smoke control.

11.44 Train (AGTS) Tunnel

11.44.1 Design Conditions

A. Summer: No ventilation, relief air only

B. Winter: No ventilation, relief air only

11.44.2 Ventilation System

The AGTS Tunnel does not have ventilation. There are relief air openings to the Concourse roof at every Concourse, along with a relief air shaft between Concourse C and the AGTS Maintenance Center, and another relief air opening at the South end of the Terminal. Air is moved by the operation of the AGTS vehicles using a piston effect.

11.44.3 Exhaust Fan Controls

The AGTS Tunnel does not have exhaust. Air is moved in the AGTS tunnel by the operation of the AGTS vehicles using a piston effect.

11.44.4 Smoke Control

All AGTS tunnel areas shall be served by a separate smoke control system. Refer to the Life Safety DSM for requirements.

11.44.5 Electrical Rooms

Electrical rooms shall have their own DX cooling system. The system shall have factory installed and wired controls and DX cooling coils. Controls for the DX units shall communicate with the EMCS to provide status and alarms.

11.45 Data Center

11.45.1 Design Conditions

Data center cooling standards are frequently subject to change. Prior to the initiation of design, consult DEN Business Technologies via the DEN PM for data center conditioning recommendations. The Consultant shall design new DEN data centers to the standards laid out by the DEN PM, or to the latest version of ASHRAE Standard 90.4 – Energy Standard for Data Centers, whichever is more stringent.

11.45.2 Ventilation System

Data centers at DEN that are not normally occupied do not require ventilation, except where required by code.

11.45.3 Exhaust Fan Controls

Data centers at DEN that are not normally occupied do not require exhaust, except where required by code.

11.45.4 Smoke Control

All DEN data centers shall be served by a separate smoke control system. Refer to the Life Safety DSM for requirements.

End of Chapter

Chapter 12 - Technical Specification Requirements

12.0 General

Designers are required to provide project specifications on all DEN projects in accordance with the Standards and Criteria DSM, Chapter 11. The project specifications should encompass all aspects of the project and be based on industry-standard construction methods and products, with content based on the DEN Standard Specifications (where available) or from an industry-standard guide specification.

12.0.1 How to Use This Chapter

12.0.1.1 DEN Standard Specifications

The DEN Standard Specifications listed in this chapter have been developed to ensure project consistency and compliance with DEN policy and procedure. For sections available as DEN Standard Specifications, the designer must obtain and use these sections for their project.

12.0.1.2 DEN Technical Requirements

This chapter, as well as similar chapters in other DSMs, provides DEN-specific requirements that must be included in nonstandard specifications for all DEN projects. An itemized list of DEN-specific technical specification requirements is provided, which may include general requirements, product requirements, and execution requirements. The designer shall incorporate these requirements into their project specification content as appropriate for the project scope. Requirements are provided in an outline format similar to construction specifications for ease of incorporation. Content may be copied directly from this chapter, with article/paragraph numbering and structure modifications as needed to ensure a cohesive document.

Note: This chapter is intended to be used as an aid to development of a project specification and ***is not intended to represent a complete specification as presented.***

The designer is responsible for developing a complete specification, incorporating the requirements of this chapter, which encompasses all aspects of the project and complies with general specification requirements outlined in the Standards & Criteria DSM, Chapter 11. After incorporating the requirements listed herein, the project specification should be reviewed to ensure it is free of redundant and/or conflicting information.

12.0.1.3 Notes to the Designer

Notes to the designer are included throughout the chapter, shown in red highlighted text. These are provided for guidance and clarification of requirements, and are intended for use only by the designer in development of their specification.

Notes to the designer shall not be incorporated into the final project specifications.

12.0.2 Specification Numbering

12.0.2.1 Numbering of Deliverables

Project deliverables should utilize Section names and numbers contained in the latest edition of *MasterFormat Numbers & Titles* at the time of project kickoff, which may vary from those in this chapter. It is the designer’s responsibility to ensure that all applicable DEN requirements are reflected accurately in the appropriate sections of the project specifications.

12.0.2.2 Numbering Provided in This Chapter

Specification section names and numbers provided in this chapter are based on *MasterFormat Numbers & Titles*, 2014 edition.

12.0.3 Product and Manufacturer Listings

Where manufacturers and products are listed in this chapter, they represent approved manufacturers and/or products. Do not include additional manufacturers and/or products for that Article or paragraph without written permission from the DEN Project Manager.

For sections without manufacturer and/or products listed in this chapter, designer shall select a basis of design based on current industry standards which complies with all applicable requirements in this and other DEN DSMs, the DEN Standard Specifications, and the Denver Building Code. Provide at least (2) acceptable alternatives to the basis of design for all products, for a total of (3) or more acceptable products, except where a sole-source selection has been approved in writing by the DEN Project Manager.

12.1 DEN Standard Mechanical Specifications

Refer to Table 12-1: Division 22 DEN Standard Specifications and Table 12-2: Division 23 DEN Standard Specifications for a listing of DEN standard mechanical specification sections. The following Sections must be obtained from the DEN Project Manager for use in the project.

Table 12-1: Division 22 DEN Standard Specifications

Section No.	Section Title
221226	Potable Water Cabinets

Table 12-2: Division 23 DEN Standard Specifications

Section No.	Section Title
230130.51	HVAC Air-Distribution System Cleaning
230596	HVAC Smoke Control Testing
236600	Preconditioned Air Hydronic Air Handling Units – Aviation
236611	Preconditioned Air DX Air Handling Units – Aviation
236614	Preconditioned Air Ductwork and Accessories – Aviation
236616	Preconditioned Air Electric Control Systems – Aviation
236619	Preconditioned Air Sequence of Operation - Aviation

12.2 DEN Technical Requirements – Division 22: Plumbing

Except where directed by designer notes, add the following requirements to all project specification sections. Where there are similar or matching specification section names, include all content below in addition to the content in the generic specifications. The content below may be omitted where related equipment, mechanical systems, and furnishments are not in the project scope.

Section 220400: Basic Plumbing Requirements

Engineer to include all aspects of this specification section throughout the project specifications. This section includes aspects that are common to multiple sections.

PART 1 GENERAL

1.01 SUMMARY

A. Provide, unless specified otherwise, all labor, materials and equipment necessary for completely finished and operational mechanical systems described and specified under other Sections of this Division 22.

B. Provide all minor incidental items such as offsets, fittings, and accessories required as part of the Work even though not specified or indicated.

1.02 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and DEN specification Division 01 Specification Sections, apply to this Division.

1.03 ALTERNATES

A. Alternates: Refer to DEN specification Section 012300 “Alternates” for description of Work in this Division affected by Alternates.

1.04 REFERENCES

A. Schedule of Referenced Organizations: Reference DEN specification Section 014210 “Referenced Material” for a list of the acronyms of organizations referenced in these Specifications.

1.05 DEFINITIONS

A. Conform to DEN specification Division 01: These Specifications are of abbreviated, simplified, or streamlined type and include incomplete sentences. Singular words will be interpreted as plural and plural words will be interpreted as singular where applicable and where full context of the Contract Documents so indicates.

B. Terminal Complex refers to the Main Terminal (Great Hall), Concourses, Central Utility Plant (CUP), Hotel, and the Transportation Center.

1.06 QUALITY CONTROL

A. Conform to DEN specification Division 01. Materials and apparatus required for the Work to be new and of first-class quality; to be furnished, delivered, erected, connected and finished in every detail; and to be so selected and arranged so as to fit properly into the building spaces.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc., or other testing agency acceptable to the authority having jurisdiction, as suitable for the purpose specified and indicated.

D. Manufacturer: Company specializing in manufacturing the Products specified in this Section with minimum three (3) years documented experience, who issues complete catalog data on total product. Products are to be of the latest design to avoid becoming untimely obsolete.

1.07 REGULATORY REQUIREMENTS

A. Comply with latest editions of the Denver Amendments to the International Codes.

B. Where hourly fire ratings are indicated or required, provide components and assemblies meeting requirements of the American Insurance Association, Factory Mutual Insurance Association and listed by Underwriters Laboratories, Inc.

C. Ensure products and installation of specified products are in conformance with recommendations and requirements of DEN's insurance underwriter.

1.08 PRODUCT OPTIONS AND SUBSTITUTIONS

A. Substitutions: Refer to DEN specification Division 01, General Requirements.

B. Some materials and equipment are specified by Manufacturer and catalog numbers. The Manufacturer and catalog numbers are used to establish a degree of quality and style for such equipment and material.

C. When alternate or substitute materials and equipment are used, Contractor shall be responsible for space requirements, configurations, performance, changes in bases, supports, structural members and openings in structure, electrical changes and other apparatus and trades that may be affected by their use.

D. When providing a product and/or service under the qualification of “acceptable equal,” Contractor shall be entirely responsible for additional costs incurred due to modifications to the civil, architectural, structural, mechanical, and electrical design that may be required to accommodate the “acceptable equal.”

E. Substitute materials and equipment are only allowed to be provided from the Manufacturers listed as approved.

1.09 SHOP DRAWINGS AND PRODUCT DATA

A. General: Comply with the General Conditions of the Contract and with DEN specification Division 01- General Requirements.

B. Shop drawings detailing fabrication and installation for metal supports and anchorage for plumbing materials and equipment.

C. In general, wood supports are not allowed for plumbing equipment. Coordinate any requirement for wood supports with the DEN project manager.

D. Prepare shop drawings according to DEN specification Division 01 to a 1/4 inch equals 1 foot scale or larger for approval from DEN Mechanical Engineer prior to start of any fabrication. Detail major elements, components, and systems of plumbing equipment and materials in relationship with other systems, installations, and building components. Show space requirements for installation and access. Show where sequence and coordination of installations are important to the efficient flow of the Work. Include the following:

1. Clearances for servicing and maintaining equipment, including space for equipment disassembly required for periodic maintenance.
2. Pump steel support details.
3. Include diagrams for power, signal, and control wiring.
4. For fabricated items, indicate dimensions, weights, and placement of openings and holes.
5. For sanitary and storm sewer systems and manholes: Include plans, elevations, sections, details, and frames and covers.
6. Show piping materials, size, locations, and inverts.
7. Include details of underground structures, connections, and cleanouts. Show interface and spatial relationship between piping and proximate structures, piping and utility services.

E. All documents shall be submitted in electronic format. Each submittal shall be in a single security free PDF document. PDF documents shall be compatible with Adobe Acrobat 10.0 or newer. All as-built documents shall be submitted in Revit in accordance with DEN specification Division 1 requirements.

F. Submittals shall constitute a representation to Owner and Engineer that Contractor has both determined and verified all quantities, dimensions, field construction criteria, materials, catalog numbers and similar data or he assumes full responsibility for doing so, and that he has coordinated each Submittal with the requirements of the Work and the Contract Documents. Contractor certifies that the Material and Equipment shown and marked on the Submittals are in compliance with the Contract Documents and can be installed, operated, and maintained in the allocated space. Submittal is to include, but not limited to, the following:

1. Piping fabrication drawings.
   a. Include in-plan view of all systems piping 2-1/2 inches and larger. Provide isometrics for piping systems or tubing 2 inches in diameter and smaller.
   b. Show the actual Equipment furnished, Equipment location by dimension, and connections.
   c. Dimension pipelines in plan view and locate in elevation. Indicate support locations.
   d. Submit before fabrication is begun.

1.10 CONTRACT RECORD DOCUMENTS

Verify requirements for as-built plans with DEN Project Manager.

A. General: Comply with the General Conditions of the Contract and with DEN specification Division 01- General Requirements.

B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 “Submittal Procedures”.

C. All as-built documents shall be submitted in Revit in accordance with DEN specification Division 1 requirements. Plans to include but not limited to:

1. Actual locations of pipe including invert elevations for Sanitary and Storm water systems. Include dimensions off of grid-lines.
2. Actual elevation of any pipe passing through a structural element (foundation walls, grade or steel beams, etc.).
3. Actual locations of flexible pipe connectors, expansion joints, anchors, and guides.
4. Actual locations of valves.
5. Actual locations of heat trace components.
6. Actual locations of hangers including attachment points.
7. Actual locations of equipment, cleanouts, backflow preventers

1.11 OPERATING AND MAINTENANCE DATA

A. Plumbing Contractor shall submit electronic copy containing a single PDF file of the entire maintenance manual to the DEN Project Manager, General Contractor for their approval.

B. The manual shall have:

1. Alphabetical list of all system components including the name, address, and 24-hour phone number of the company responsible for servicing each item during the first year's operation.
2. Operating instructions for complete system, including emergency procedures for fire or failure of major equipment and procedures for normal starting/operating/shutdown and long-term shutdown.
3. Maintenance instructions, including valves, valve tag and other identified equipment lists, proper lubricants and lubricating instructions for each piece of equipment and necessary cleaning/replacing/adjusting schedules. Include installation instructions, spare parts lists and exploded assembly views.
4. Operation Data: Indicate frequency of treatment required for interceptors.
5. Manufacturer's data on each piece of equipment, including:
   a. Installation instructions.
   b. Drawings and specifications (approved shop drawings).
   c. Parts lists.
   d. Complete wiring and temperature control diagrams (approved shop drawings).

6. Each piece identified on any schedule shall be bookmarked in the electronic file by its scheduled tag ID (IE: TML_04_11A_EWH_01)

C. In addition to the maintenance manual, and keyed to it, the equipment shall be identified and tagged as specified.

1. Identify all starters, disconnect switches, and manually operated controls, except integral equipment switches with permanently applied, legible markers corresponding to operating instructions in the “Maintenance Manual”.
2. Tag all manual operating valves with 1-1/2" diameter brass tags attached with chains. Tags are to be sequence numbered with legible metal stamps.
3. Provide a typed tag list or schedule mounted under glass in the room designated by DEN Project Manager stating number, location, and function of each tagged item. Insert a copy of tag list in each “Maintenance Manual”.

D. Plumbing Contractor shall be responsible for scheduling instructional meetings for maintenance personnel on the proper operation and maintenance of all mechanical systems, using the maintenance manual as a guide. These meetings must be scheduled through the DEN Project Manager, and General Contractor far enough in advance so that all personnel can be notified.

1.12 FINAL OBSERVATION

A. Comply with the requirements of DEN specification Division 01 and the following:

1. Prior to the request for final observation, all Work under the contract shall be complete; all systems shall be in proper working order and placed in operation for a minimum duration of 48 hours.
2. All equipment shall be cleaned. All debris and construction materials shall be removed from the DEN property to a DEN approved landfill off-airport.
3. At the request of the DEN Project Manager, a representative of the Contractor who is thoroughly familiar with the Project and operation of the various systems shall be present during the final observation to demonstrate proper operation of the equipment and controls. If requested by the DEN Project Manager, the Contractor shall have representatives from the Contractor's subcontractors present to assist during final observation.

1.13 PROJECT CONDITIONS

A. Accessibility:

1. Division 22 Contractor shall locate all equipment, which must be serviced, operated, or maintained in fully accessible positions. Such equipment shall include (but not be limited to) valves, shock absorbers, motors, controllers, switchgear, and drain points. If required for better accessibility, furnish access doors for this purpose. Minor deviations from Drawings may be allowed to provide for better accessibility. Any changes shall be approved by the DEN Project Manager prior to making the change.
2. Division 22 Contractor shall provide the General Contractor with the exact locations of access doors for each concealed valve, shock absorber control, damper, or other device requiring service. Locations of these doors shall be submitted in sufficient time to be installed in the normal course of work.

B. Freeze Protection:

1. Do not run plumbing systems piping in outside walls, or locations where freezing may occur. Piping next to outside walls shall be in furred spaces with insulation between the piping and the outside wall. Insulation of piping shall not be considered freeze protection.

C. Interruption of Existing Water, Storm or Sanitary Sewer Service: Do not interrupt services to facilities occupied by DEN, DEN Tenant or others unless permitted under the following conditions and then only after arranging to provide temporary services according to requirements indicated:

1. Notify DEN Project Manager no fewer than seven (7) days in advance of proposed interruption of water service.
2. Do not interrupt services without DEN Project Manager's written permission.
3. Comply with DEN specification Division 01.

1.14 COORDINATION

A. General: Coordinate and order the progress of plumbing Work to conform to the progress of the Work of the other trades. Complete the entire installation as soon as the condition of the building will permit.

B. Coordinate Work with Division 21 Fire Suppression, Division 23 HVAC, Division 26 Electrical, and Division 33 Utilities and other Divisions as required to perform the Work.

C. Cutting and Patching: Reference Section 017330 “Cutting and Patching”.

D. Discrepancies: Examine Drawings and Specifications for other parts of the Work, and if any discrepancies occur between the plans for the Work of this Division and the plans for the work of others, report such discrepancies to the DEN Project Manager and obtain written instructions for any changes necessary.

E. Order of Precedence: The precedence of construction documents are as Specified in the General Conditions.

F. For any work done in the Central Utility Plant (CUP) provide schedule specific to work to be done above, or around any existing equipment to DEN Project Manager and CUP operators at least 2 weeks prior to start of work.

1.15 START-UP PROCEDURES

A. Before start-up, each piece of equipment comprising a part of the system shall be checked for proper lubrication, drive rotation, proper control sequence, and any other condition, which may cause damage to equipment or endanger personnel.

B. Ensure that all control systems are fully operational in automatic mode.

C. If systems are not to continue in use following the start-up procedures, steps should be taken to ensure against accidental operation or operation by unauthorized personnel.

D. Factory personnel shall be notified as appropriate to start systems requiring their services.

E. Notify the DEN Project Manager in writing a minimum of 72 hours prior to start-up of all major mechanical equipment and systems if no shutdown request is required.

F. Should there be any equipment found which had not been properly started up, it will be the responsibility of this Contractor to arrange for the appropriate personnel to start up the equipment at the Contractor's expense and at a time as scheduled by the DEN Project Manager.

1.16 SCHEDULE OF TESTING

A. Provide testing in accordance with the General Conditions of the Contract.

B. A schedule of testing shall be drawn up by the Division 22 Contractor in such a manner that it will show areas tested, test pressure, length of test, date, time and signature of testing personnel.

C. Notify the DEN Project Manager, DEN Mechanical Inspector and DEN Mechanical Engineer in writing a minimum of 72 hours prior to testing of any mechanical equipment and systems if no shutdown request is required.

D. All testing must be performed in the presence DEN Project Manager and or designated representative; the DEN Project Manager's signature for verification of the test must appear on the schedule.

E. All testing must be performed in accord with the procedures set forth in Division 22 and other Sections of the Specifications where referenced. At completion of testing, the schedule shall then be submitted in triplicate to the DEN Project Manager.

F. Ensure operational and performance tests are made on seasonal equipment.

G. Complete all tests required by Code Authorities, such as health codes, building codes, and safety codes.

H. After test runs have been completed and systems have been demonstrated to be satisfactory and ready for permanent operation, all permanent pipeline strainers and filters shall be cleaned, valve and pump packing properly adjusted, final adjustments made, drive guards secured in place, lubrication checked and replenished if required.

1.17 EXTRA MATERIALS

A. Extra stock materials may not be allowed on publicly funded projects. Coordinate extra stock submittal requirements with DEN Project Manager.

1.18 WARRANTIES

Coordinate warranty requirements with DEN Project Manager.

A. Conform to DEN specification Division 01: Provide a written warranty covering the entire plumbing Work to be free from defective materials, equipment, and workmanship for a minimum period of two (2) years after date of acceptance. During this period, provide labor and materials as required to repair or replace defects.

1. Provide certificates for such items of equipment, which have or are specified to have warranties in excess of two (2) years.

PART 2 PRODUCTS

PART 3 EXECUTION

Section 220500: Common Work Results for Plumbing Equipment

Engineer to include all aspects of this specification section though out the project specifications. This section includes aspects that are common to multiple sections.

PART 1 GENERAL

1.01 SUMMARY

A. This Section includes the following basic mechanical materials and methods to complement other Division 22 Sections.

1.02 RELATED SECTIONS

A. Drawings and general provisions of Contract, including General and the Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

Use DEN standard welding specification when welding is required for piping or supports. No other welding specifications will be acceptable.

B. Section 050510 “Welding”

1.03 DEFINITIONS

A. Pipe, pipe fittings, and piping include tube, tube fittings, and tubing.

B. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe and duct shafts, unheated spaces immediately below the roof, spaces above ceilings, unexcavated spaces, crawl spaces, and tunnels.

C. Exposed Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.

D. Exposed Exterior Installations: Exposed to view outdoors, or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.

E. Concealed Interior Installations: Concealed from view and protected from physical contact by building occupants. Examples include above ceilings and in duct shafts.

F. Concealed Exterior Installations: Concealed from view and protected from weather conditions and physical contact by building occupants, but subject to outdoor ambient temperatures. Examples include installations within unheated shelters.

Delegated design of vibration isolators, pipe expansion, pipe supports, equipment supports, etc. and associated attachments is not allowed at DEN. Engineer is responsible for providing the necessary details needed for the scope of work. Remove all references to delegated design of these items from Specifications.

1.04 SUBMITTALS

A. General: Submit the following according to the Conditions of the Contract and DEN specification Division 01 Specification Sections:

1. Product Data: For each type of product indicated.
   a. Submit manufacturer's technical product data and installation instructions for system materials and products.
   b. Include data substantiating that materials comply with requirements.
   c. Provide component sizes, rough-in requirements, service sizes, and finishes.
2. Welder certificates signed by Contractor certifying that welders comply with requirements specified under the Quality Assurance Article.
3. Floor x-rays and/or ground penetrating radar reports.
4. All documents shall be submitted in electronic format. Each submittal shall be in a single security free PDF document. PDF documents shall be compatible with Adobe Acrobat 10.0 or newer. All as-built documents shall be submitted in Revit in accordance with DEN specification Division 1 requirements.

Do not delete spool drawings paragraph if welded piping is used.

5. Contractor shall submit fully dimensioned spool drawings for all welded piping work. Drawings shall indicate all weld types, sizes and materials to be used. The spool drawing size shall match the full-size contract documents of either 24"x36" or 34"x44". Spool drawings shall be submitted in electronic format in Revit in compliance with DEN specification Division 1 requirements. Files shall not contain security. Other file formats will not be accepted. This requirement is for welded piping only and is used for the ITA and DEN quality assurance personnel. Do not delete if welded piping is used.
6. Field Test Reports: Written reports of each pressure tests specified in Division 22 Sections. Include the following:
   a. Test procedures used.
   b. Test results that comply with requirements.
   c. Failed test results and corrective action taken to achieve requirements.

1.05 QUALITY CONTROL

A. Equipment Selection: Equipment of greater or larger power, dimensions, capacities, and ratings may be furnished provided such proposed equipment is approved in writing by the DEN Project Manager and connecting mechanical and electrical services, circuit breakers, conduit, motors, bases, and equipment spaces are increased. No additional costs will be approved for these increases, if larger equipment is approved. If minimum energy ratings or efficiencies of the equipment are specified, the equipment must meet the design requirements and commissioning requirements.

B. Electronic Equipment Compliance:

1. Contractor warrants that all equipment, devices, items, systems, software, hardware, or firmware provided shall properly, appropriately, and consistently function and accurately process date and time data (including without limitation: calculating, comparing, and sequencing). This warranty supersedes anything in the Specifications or other Contract Documents which might be construed inconsistently. This warranty is applicable whether the equipment, device, item, system, software, hardware, or firmware is specified with or without reference to a manufacturer's name, make, or model number.

C. Unless specified otherwise, all materials and equipment shall be of domestic (USA) manufacture and shall be of the best quality used for the purpose in commercial practice.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Deliver pipes and tubes with factory-applied end-caps. Maintain end-caps through shipping, storage, and handling to prevent pipe-end damage and prevent entrance of dirt, debris, and moisture.

B. Protect stored, pipes and tubes from moisture and dirt. Elevate above grade. When stored inside, do not exceed structural capacity of the floor.

C. Store plastic pipes protected from direct sunlight. Support to prevent sagging and bending.

D. Protect flanges, fittings, and piping specialties from moisture and dirt.

E. Deliver fittings with plastic sheeting to protect it from elements. Inspect duct liner for exposure to dirt and tears.

1.07 SEQUENCING AND SCHEDULING

A. Coordinate plumbing equipment installation with other building components.

B. Coordinate the installation of required supporting devices.

C. Sequence, coordinate, and integrate installations of plumbing materials and equipment for efficient flow of the Work.

D. Coordinate connection of electrical services.

E. Coordinate installation of identifying devices after completing covering and painting where devices are applied to surfaces.

PART 2 PRODUCTS

2.01 JOINING MATERIALS

Grooved Mechanical Couplings: Acceptable only for fire protection piping; not acceptable for any other applications.

Push-on or press-on types of connectors are not allowed.

A. Pipe Flange Gasket Materials: Suitable for the chemical, pressure, and thermal conditions of the piping system contents.

1. ASME B16.21, nonmetallic, flat, asbestos-free, 1/8-inch maximum thickness, except where thickness or specific material is indicated.
   a. Full-Face Type: For flat-face, Class 125 cast-iron and cast-bronze flanges.
   b. Narrow-Face Type: For raised-face, Class 250 cast-iron and steel flanges.
2. Solder Filler Metal: ASTM B 32.
3. Alloy Sn95 or Alloy Sn94: Tin (approximately 95 percent) and silver (approximately 5 percent) – Not industry standard, usually 5% antimony.

B. Brazing Filler Metals: AWS A5.8.

1. BCuP Series: Copper-phosphorus alloys.
2. BAg1: Silver alloy.

C. Welding Filler Metals: Comply with AWS D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded. All welding rod is to be kept in an operable rod oven at all times

2.02 BACKFILL

A. Flowable Backfill: Designed in accordance with ASTM C 94 and ASTM D 4832.

1. Refer to Section 033350 “Flowable Backfill Low-Strength Concrete” for material and installation requirements.
2. Minimum Requirements:
   a. Compressive Strength: 50-100 psi
   b. Slump: 6-8 inches.
3. Required for all piping and ductwork installed below concrete slabs, apron paving and roadways.

B. Other methods of backfill for these areas is prohibited. No exceptions will be allowed.

PART 3 EXECUTION

3.01 PIPING SYSTEMS- COMMON REQUIREMENTS

A. Piping Connections: Except as otherwise indicated, make piping connections as specified below.

1. Install unions in piping 2 inches and smaller adjacent to each valve and at final connection to each piece of equipment having a 2-inch or smaller threaded pipe connection.
2. Wet Piping Systems: Install dielectric coupling and nipple fittings to connect piping materials of dissimilar metals.

B. Piping below apron, concrete slabs or paving shall be encased in flowable backfills.

C. Install manual air vents at high points of system and drains, consisting of a tee fitting, NPS 3/4 Ball valve, and short NPS 3/4 threaded nipple with cap, at low points in piping system mains and elsewhere as required for system drainage.

D. Install piping to permit valve servicing.

3.02 EQUIPMENT INSTALLATION- COMMON REQUIREMENTS

A. Install equipment to provide the maximum possible headroom where mounting heights are not indicated.

B. Install equipment according to approved submittal data. Portions of the Work are shown only in diagrammatic form. Refer conflicts to the DEN Project Manager.

C. Install equipment level and plumb, parallel and perpendicular to other building systems and components in exposed interior spaces, except where otherwise indicated.

D. Install plumbing equipment to facilitate servicing, maintenance, and repair or replacement of equipment components. Connect equipment for ease of disconnecting, with minimum of interference with other installations. Extend grease fittings to an accessible location.

E. Install equipment giving right-of-way to piping systems installed at a required slope.

3.03 PAINTING AND FINISHING

Division 09 sections specify paint products for various surfaces (e.g., ferrous and nonferrous metals and insulation jackets), items to be field painted, application methods, and coating systems (number of prime and finish coatings and coating thicknesses). Coordinate these requirements with Architect to ensure that appropriate painting requirements are retained in these Division 09 sections.

A. Paint color schedule shall conform to ASME A13.1-1996," Scheme for the Identification of Piping Systems."

B. Damage and Touch Up: Repair marred and damaged factory-painted finishes with materials and procedures to match original factory finish.

C. All rooftop equipment exposed to public or aircraft view shall be painted flat white or grey in accordance with Division 09.

3.04 CONCRETE PENETRATIONS

DEN specification Division 01 and Division 02 Sections have specific requirements for x-raying and GPR. Coordinate the paragraphs below with Project and other specification Sections.

Reference DEN Specification Section 017330 "Cutting and Patching" for core drilling and saw cutting requirements.

Reference DEN Specification Section 024119 "Selective Demolition" for demolition and removal of selected portions of a building or structure, and repair procedures for selective demolition operations.

A. All penetrations required through completed concrete construction shall be core drilled or saw cut at minimum size required. All penetrations in concrete require an x-ray or ground penetrating radar to determine if the location is clear of reinforcing steel and embedded systems. Precautions shall be taken when drilling to prevent damage to structural concrete.

1. The Contractor shall provide an interpretation of the x-rays or radar shot and obtain written acceptance from the DEN Project Manager before proceeding with drilling.

3.05 WELDING

Where welding is required for framing of openings, drain pans, or duct-pipe supports, Section 050510 "Welding" shall be included. No exceptions. The following paragraphs shall be included in the specifications:

A. Qualify welding processes and operators for structural steel according to AWS D1.1/D1.1M Structural Welding Code- Steel. Additional standards include:

1. AWS D1.2.
2. AWS D1.3.
3. AWS D1.4.
4. See Division 05 for additional requirements.

B. All welding shall be inspected in process by a contractor-provided, Certified, Independent Testing Agency by an AWS certified welding inspector.

C. Qualify welding processes and operators for piping according to ASME Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications.

1. Comply with provisions of ASME B31 Series "Code for Pressure Piping."
2. Certify that each welder has passed AWS qualification tests for the welding processes involved and that certification is current.

3.06 ERECTION OF METAL SUPPORTS AND ANCHORAGE

No steel shall be generally specified on the drawings. Include the appropriate Division 05 specifications.

A. Cut, fit, and place miscellaneous metal supports accurately in location, alignment, and elevation to support and anchor mechanical materials and equipment.

B. Field Welding: Comply with AWS D1.1 Structural Welding Code- Steel, as referenced in Part 1.

C. Notify DEN Project Manager if more supports are needed that what is shown.

3.07 DEMOLITION

DEN has specific demolition restrictions. Coordinate requirements of this Section with DEN specification Division 01 and Division 02 and DEN Project Manager

A. Where pipe, insulation, or equipment to remain is damaged or disturbed, remove damaged portions and install new products of equal capacity and quality.

B. Temporary Disconnection: Remove, store, clean, reinstall, reconnect, and make operational equipment indicated for relocation.

C. Disconnect, demolish, and remove plumbing systems, equipment, and components indicated to be removed.

1. Piping to Be Removed: Remove portion of piping and associated supports indicated to be removed, provide a shutoff valve with plug or cap in pressurized systems and cap or plug remaining piping with same or compatible piping material. No piping shall be abandoned in place. Repair insulation.
2. Equipment to Be Removed: Disconnect and cap services and remove equipment.
3. Equipment to Be Removed and Reinstalled: Disconnect and cap services and remove, clean, and store equipment; when appropriate, reinstall, reconnect, and make equipment operational.
4. Equipment to Be Removed and Salvaged: Disconnect and cap services and remove equipment and deliver to DEN Project Manager.
5. If pipe, insulation, or equipment to remain is damaged in appearance or is unserviceable, remove damaged or unserviceable portions and replace with new products of equal capacity and quality.
6. Repair structure floor, ceilings, roof, slabs from removed supports in accordance with Division 03, Division 05, and/or Division 09 as required for the project.

Section 220505: Coatings and Corrosion Protection

PART 1 GENERAL

1.01 MAINTENANCE MATERIALS

Maintenance materials may not be allowed on publicly funded projects.

Coordinate maintenance material submittal requirements with DEN Project Manager.

A. Leave on premises, where directed by the DEN Project Manager, not less than one (1) unopened gallon of each field-applied paint product and color used.

B. Containers shall be tightly sealed and clearly labeled for identification.

PART 2 PRODUCTS

2.01 SHOP-APPLIED EXTERNAL PROTECTIVE PIPE COATING

A. Coating system shall meet the following specifications:

1. Dry film thickness shall be spot checked at random on ten percent of the coated surfaces. If film thickness is not found to be uniform and to specification, the Contractor shall apply additional coats at no cost to the Owner until the specified film thickness has been obtained.

a. Dry film thickness shall be checked by the Contractor at the Contractor's expense.

b. Provide complete records of dry film thickness measurements to DEN Project Manager.

B. If, in the opinion of the DEN Project Manager, the coatings show ridges, waves, runs or holidays indicating uneven coverage or improper application, the Contractor shall be required to remove and reapply the coating at no cost to the Owner.

2.02 FIELD OR SHOP APPLIED INTERNAL TANK LINING

A. Thoroughly examine surfaces scheduled to be painted and coated prior to commencement of work. Report in writing, to DEN Project Manager, any condition that may potentially affect proper application. Do not commence until such defects have been corrected.

PART 3 EXECUTION

3.01 CERTIFICATION

A. A log of mill procedure and quality control tests shall be kept daily by the coating, lining and wrapping applicator(s) and a certified copy of this log(s) shall be submitted to the DEN Project Manager with each delivery of pipe and equipment.

Section 220516: Expansion Fittings and Loops for Plumbing Piping

PART 1 GENERAL

All equipment supports and thermal expansion compensation shall be manufactured systems or designed and detailed by a Colorado Registered Professional Engineer. Supports shall be coordinated with Architectural and Structural disciplines. Under no circumstances shall the construction documents direct a Contractor to provide supports without detailed performance specifications outlining criteria and requirements of supports and their design and installation.

Delegated design of expansion fittings and loops for plumbing piping is not allowed at DEN. Engineer is responsible for providing design for size, location, supports, etc. Remove all references to delegated design of hangers from Specifications

1.01 ACTION SUBMITTALS

A. Product Data: For each type of product indicated, and as follows:

1. Include data substantiating that materials comply with requirements.

2. Flexible Pipe Connectors: Indicate maximum temperature and pressure rating, face-to-face length, live length, hose wall thickness, fundamental frequency of assembly, braid structure, and total number of wires in braid.

3. Expansion Joints: Indicate maximum temperature and pressure rating, and the estimated number of full flexures before joint failure. Provide multi-wall convoluted bellows where possible to reduce joint end force reactions on building structure.

B. Shop Drawings:

1. Expansion Joints: Submit for each assembly shop drawings, along with procedures applied in making selections as appropriate to lifetime cycles ratings specified. Identify materials of construction and indicate maximum temperature and pressure ratings.

PART 2 PRODUCTS

Engineer to select apparatus that exceed required test pressures and operational temperatures. Verify that specified items meet these requirements. Indicate both operational and test pressures, basis of design pressure and corresponding temperature, and operational temperatures for each apparatus in the specifications or schedule in the Construction Documents.

Engineer to select metal bellows type of flex connections to pumps or equipment 4" in diameter or larger. Stainless-steel braided connectors to be used only with permission from DEN Mechanical Engineer and shall not have rubber sleeves. Rubber types of flex connectors are not allowed.

Engineer to select braided stainless-steel flex connectors for connections to equipment smaller than 4" in diameter. Braided stainless-steel connectors are not to include rubber internal sleeves.

PART 3 EXECUTION

3.01 INSPECTION

A. Examine piping layout and notify DEN Project Manager of additional anchors or expansion joints required to adequately protect system.

B. Provide inspection services by flexible pipe manufacturer's representative for final installing and certify installation is in accordance with manufacturer's recommendations and connectors are performing satisfactorily.

Section 220517: Sleeves and Sleeve Seals for Plumbing Piping

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Submit product samples if requested by DEN Project Manager.

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 CONCRETE PENETRATIONS

DEN Division 01 and Division 02 Sections have specific requirements for x-raying and GPR. Coordinate the paragraphs below with Project and other specification Sections.

Reference Section 017330 “Cutting and Patching” for core drilling and saw cutting requirements.

Reference Section 024119 “Selective Demolition” for demolition and removal of selected portions of a building or structure, and repair procedures for selective demolition operations.

Where Engineer is presented with choices between silicone sealant and grout, Engineer shall select grout.

A. All penetrations required through completed concrete construction shall be core drilled or saw cut at minimum size required. All penetrations in concrete require an x-ray or ground penetrating radar to determine if the location is clear of reinforcing steel and embedded systems. Precautions shall be taken when drilling to prevent damage to structural concrete.

B. The Contractor shall provide an interpretation of the x-rays or radar shot and obtain written acceptance from the DEN Project Manager before proceeding with drilling.

Section 220519: Meters and Gauges for Plumbing Piping

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Product Data: For each type of product indicated.

1. Provide list, which indicates use, operating range, total range and location for manufactured components.
2. Include data substantiating that materials comply with requirements.

PART 2 PRODUCTS

2.01 STEM TYPE THERMOMETERS

A. 9 inch scale, Lexan window and degrees F calibration

2.02 DIAL THERMOMETERS

A. 3 inch for field mount equipment, and 5 inch for mechanical room equipment.

PART 3 EXECUTION

Section 220523: General-Duty Valves for Plumbing Piping

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Product Data: For each type of valve indicated.

1. Include data substantiating that materials comply with requirements.
2. Provide manufacturers catalog information. Indicate valve data and ratings.

PART 2 PRODUCTS

2.01 GATE VALVES

A. In general, Gate Valves should not be used except for equipment for which Gate Valves are the only option for isolation valves, e.g., some manufacturers of backflow preventers. For all other instances, engineer should attempt to find an alternative solution to using Gate Valves.

2.02 BALL VALVES

A. Two-piece ball valves with a full port are recommended for most services. One-piece ball valves have a reduced port and one fewer leak path. Three-piece ball valves are recommended if disassembly without removing valve from piping is required.

B. For corrosive or high-temperature applications, use stainless-steel-trim three-piece ball valves.

PART 3 EXECUTION

Section 220529: Hangers and Supports for Plumbing Piping and Equipment

PART 1 GENERAL

1.01 PERFORMANCE REQUIREMENTS

All equipment supports and thermal expansion compensation shall be manufactured systems or designed and detailed by a Colorado Registered Professional Engineer. Supports shall be coordinated with Architectural and Structural disciplines. Under no circumstances shall the construction documents direct a Contractor to provide supports without detailed performance specifications outlining criteria and requirements of supports and their design and installation.

Delegated design of hangers is not allowed at DEN. Remove all references to delegated design of hangers from Specifications.

The following hanger material types are not allowed at DEN. Remove all references the following hanger material types from Specifications: Copper, Aluminum, Fiberglass, and Plastic

Only MFMA Manufacturers are allowed for metal framing systems. Remove all references to non-MFMA Manufacturers' metal framing systems from Specifications.

The following hanger types are not allowed at DEN. Remove all references to the following hanger types from Specifications: Snubbers, Rigid-Type Restraints and Accessories, Cable-Type Restraints and Accessories, Post-Installed Concrete Anchors, and Concrete Inserts.

Powder-Actuated Fasteners are not allowed at DEN. Remove all references to Powder-Actuated Fasteners from Specifications.

A. The following hanger material types are not allowed at DEN. Remove all references the following hanger material types from Specifications: Copper, Aluminum, Fiberglass, and Plastic

B. Only MFMA Manufacturers are allowed for metal framing systems. Remove all references to non-MFMA Manufacturers' metal framing systems from Specifications.

C. The following hanger types are not allowed at DEN. Remove all references to the following hanger types from Specifications: Snubbers, Rigid-Type Restraints and Accessories, Cable-Type Restraints and Accessories, Post-Installed Concrete Anchors, and Concrete Inserts.

1.02 REFERENCES

A. Materials and workmanship shall conform to the latest issue of all industry standards, publications, or regulations referenced in this section and with the following references as applicable. Refer to Section 014200 “References” for listing of issuing organizations or agencies.

B. Applicable Standards:

1. ASME International (ASME):
   a. B31.1- Power Piping.
   b. B31.9- Building Services Piping.

1.03 ACTION SUBMITTALS

A. Product Data: For each type of product indicated, and as follows:

1. Steel pipe hangers and supports.
2. Thermal-hanger shield inserts.
3. Pipe positioning systems.
4. Include data substantiating that materials comply with requirements.

B. Refer to Section 220400 “Basic Plumbing Requirements” for coordination requirements.

PART 2 PRODUCTS

2.01 FASTENER SYSTEMS

A. Powder actuated fasteners are not allowed in the Terminal or Concourse areas and should not be specified. They are allowed on remote buildings separate from the airfield. Coordinate specification of powder-actuated fasteners with DEN Project Manager.

PART 3 EXECUTION

3.01 PIPE HANGERS AND SUPPORTS

A. Mechanical systems shall not share supports and/or hangers with any other systems. This is a DEN and NEC requirement and shall not be deleted.

3.02 HANGER AND SUPPORT APPLICATIONS

A. Horizontal-Piping Hangers and Supports. Use of Adjustable Roller Hangers (MSS Type 43) shall only be used with written permission from DEN Mechanical Engineer.

3.03 HANGER AND SUPPORT SYSTEM

A. Insulated Piping:

1. Attach clamps and spacers to piping.
   a. Piping Operating above Ambient Air Temperature: Clamp may project through insulation.
   b. Piping Operating below Ambient Air Temperature: Use thermal-hanger shield insert with clamp sized to match OD of insert.
   c. Do not exceed pipe stress limits allowed by ASME B31.9 for building services piping.
2. Install MSS SP-58, Type 39, protection saddles if insulation without vapor barrier is indicated. Fill interior voids with insulation that matches adjoining insulation.
   a. Option: Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 and larger if pipe is installed on rollers.
3. Install MSS SP-58, Type 40, protective shields on cold piping with vapor barrier. Shields shall span an arc of 180 degrees.
   a. Option: Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 and larger if pipe is installed on rollers.
4. Shield Dimensions for Pipe: Not less than the following:
   a. NPS 1/4 to NPS 3-1/2: 12 inches long and 0.048 inch thick.
   b. NPS 4: 12 inches long and 0.06 inch thick.
   c. NPS 5 and NPS 6: 18 inches long and 0.06 inch thick.
   d. NPS 8 to NPS 14: 24 inches long and 0.075 inch thick.
   e. NPS 16 to NPS 24: 24 inches long and 0.105 inch thick.
5. Pipes NPS 8 and Larger: Include wood inserts of length at least as long as protective shield.
6. Insert Material: Length at least as long as protective shield.
7. Thermal-Hanger Shields: Install with insulation same thickness as piping insulation.

Section 220533: Heat Tracing for Plumbing Piping

PART 1 GENERAL

1.01 GENERAL

A. Heat trace systems are not considered best practice and shall only be considered when no other option exists. Obtain written permission from DEN Mechanical Engineer.

B. If heat trace systems are allowed, then system to include controls with BACNet interface to EMCS for notification of failure in the system. Include integration into the EMCS for operational status and failure notification to maintenance Staff.

Heat trace as described in this DSM apply to both plumbing and HVAC piping.

1.02 WARRANTY

A. Coordinate warranty requirements with DEN Project Manager.

1. Special Warranty: Manufacturer agrees to repair or replace electric heating cable that fails in materials or workmanship within specified warranty period.

B. Verify available warranties and warranty periods for electric heating cable. Special warranties often exclude labor.

C. Warranty Period: Minimum three (3) years from date of Substantial Completion

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 INSTALLATION

A. Indicate location of controls on Drawings.

B. Install warning tape on piping insulation where piping is equipped with electric heating cables.

Section 220548.13: Vibration Controls for Plumbing Piping and Equipment

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Product Data: For each type of product.

B. Include rated load, rated deflection, and overload capacity for each vibration isolation device.

C. Illustrate and indicate style, material, strength, fastening provision, and finish for each type and size of vibration isolation device type required.

D. Include data substantiating that materials comply with requirements.

1.02 SHOP DRAWINGS:

A. Detail fabrication and assembly of equipment bases. Detail fabrication including anchorages and attachments to structure and to supported equipment.

B. Indicate inertia bases and locate vibration isolators, with static and dynamic load on each.

Retain “Delegated-Design Submittal” Paragraph below if design services have been delegated to Contractor.

C. Delegated-Design Submittal: For each vibration isolation device.

1. Include design calculations for selecting vibration isolators.

PART 2 PRODUCTS

PART 3 EXECUTION

Section 220553: Identification for Plumbing Piping and Equipment

PART 1 GENERAL

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 EQUIPMENT LABEL INSTALLATION

A. Equipment: Identify air handling units, pumps, heat transfer equipment, tanks, and water treatment devices with plastic nameplates or stencil painting. Small devices, such as in-line pumps, may be identified with metal tags. At a minimum, the nameplate shall contain the following information:

1. Equipment tag.
2. Equipment location.
3. Service area.
4. Flowrate (cfm/gpm).
5. Capacity (btuh/kw).

Item below shall be edited to reflect who owns and will maintain the equipment installed. For all tenant projects, this shall be edited to the name of the space (i.e., McDonald's). Item shall be deleted for all DEN systems.

6. <Equipment Owner>

B. Equipment and terminal devices above ceiling:

1. Provide adhesive backed plastic nameplate on ceiling grid support directly below equipment identifying unit tag and temperature control node number.
2. Label drop ceilings and access panes with locations of shutoff valves and plumbing equipment located above ceilings.

3.02 CONTROLS

A. Identify control panels and major control components outside panels with plastic nameplates.

B. Key to control schematics.

3.03 VALVE-TAG IDENTIFICATION AND INSTALLATION

A. Use metal tags secured with brass 'S' hooks or brass chains.

B. Stamp tags with a unique prefix to identify system to which applied, followed by a number (example: CW-1, CW-2, etc.). In general, prefix shall match system abbreviations used on drawings where applicable.

C. Provide a typewritten listing of valves (VALVE CHART AND SCHEDULE) including: Valve identification number, location, function, normal position, service, and area served. Mount list as specified and directed. Include additional copy in operation and maintenance manuals. Show valve tag designations on the project record document drawings, including schematic flow diagrams where included with construction documents.

D. Automatic control valves shall be tagged to match designations shown on the temperature control drawings.

3.04 VALVE CHART AND SCHEDULE

A. Provide valve chart and schedule in aluminum frame with clear plastic shield. Install at location as directed by DEN Project Manager. See example below:

TAG #	Location	Function	Normal Position	Service	Area Served
CW-1	TML_05_11W_064	Isolation	OPEN	Domestic CW	Urinals in TML_05_11W_104
CW-2	TML_05_11W_064	Isolation	OPEN	Domestic CW	Lavs in TML_05_11W_104
CW-3	TML_05_11W_074	Isolation	OPEN	Domestic CW	DWH-1 for TML_05_11W_104
HW-1	TML_05_11W_064	Isolation	OPEN	Domestic HW	Lavs in TML_05_11W_104
HW-2	TML_05_11W_074	Isolation	OPEN	Domestic HW	DWH-1 for TML_05_11W_104
HWR-1	TML_05_11W_064	Balancing	52% Open	Domestic HWR	Lavs in TML_05_11W_104

3.05 PIPING IDENTIFICATION SCHEDULE

A. For Natural Gas, L.P. Gas and Gas Vent piping, paint entire pipe color indicated except, for vent piping exposed on exterior of building, paint pipe to match wall color. Certain locations may be exempt by direction of DEN Project Manager.

B. Pipe identification and color coding for general-use piping systems shall be in accordance with the following schedule:

Classification:	Band Color:	Stenciled Legend:
Domestic Hot Water	Yellow	Domestic Hot Water
Domestic Cold Water	Green	Domestic Cold Water
Domestic Hot Water Circ.	Yellow	Domestic H. W. Circ.
Chilled Drinking Water	Green	Ch. Drink Water
Non-Potable Water	Yellow	Non-Potable Water
Natural Gas*	Yellow	Nat. Gas
L.P. Gas*	Yellow	L.P. Gas
Gas Vent*	Yellow	Gas Vent
Soil and Waste Piping	Green	Soil & Waste
Plumbing Vent	Green	Vent
Plumbing Drain	Green	Drain
Roof Drain	Green	Roof Drain
Humidifier	Green	Humidifier
Expansion Tank No.	Yellow	Exp. Tank No.
Soft Water	Green	Soft Water
Condensate Drain	Yellow	Cond. Drain
Condensate Overflow	Yellow	Cond. Overflow
Lawn Sprinkler Supply	Green	Lawn Spr. Supp.

**Paint entire pipe color indicated except, for vent piping exposed on exterior of building, paint pipe to match wall color. Certain locations may be exempt by direction of DEN Project Manager.*

C. Overflow condensate drain termination shall have a minimum 6"x6" placard that reads as follows:

1. “If water is observed from the pipe below, immediately contact Maintenance Control at (303) 342-2800”.
2. Placard shall have white background with red lettering.
3. Minimum lettering height shall be ½".
4. Mount placard a minimum of 48" above finish floor.

D. Paint exterior piping systems to match wall colors.

Section 220716: Plumbing Equipment Insulation

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.

1. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.

2. Detail attachment and covering of heat tracing inside insulation.
3. Detail removable insulation at equipment connections and access panels.
4. Detail application of field-applied jackets.
5. Detail application at linkages of control devices.
6. Detail field application for each equipment type.

B. Samples: Coordinate sample requirements with DEN Project Manager. For each type of insulation and jacket indicated. Identify each Sample, describing product and intended use. Sample sizes are as follows:

1. Sheet Form Insulation Materials: 12 inches square.
2. Sheet Jacket Materials: 12 inches square.
3. Manufacturer's Color Charts: For products where color is specified, show the full range of colors available for each type of finish material.

1.02 QUALITY ASSURANCE

A. Mockups: Before installing insulation, build mockups for each type of insulation and finish listed below to demonstrate quality of insulation application and finishes. Build mockups in the location indicated or, if not indicated, as directed by DEN Project Manager. Use materials indicated for the completed Work.

1. Equipment Mockups: One tank or vessel, and one pump.
2. For each mockup, fabricate cutaway sections to allow observation of application details for insulation materials, adhesives, mastics, attachments, and jackets.
3. Notify DEN Project Manager seven (7) days in advance of dates and times when mockups will be constructed.
4. Obtain DEN Project Manager's approval of mockups before starting insulation application.
5. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless DEN Project Manager specifically approves such deviations in writing.
6. Maintain mockups during construction in an undisturbed condition as a standard for judging the completed Work.
7. Demolish and remove mockups when directed.

PART 2 PRODUCTS

2.01 FIELD-APPLIED JACKETS

A. Color-code jackets based on system. Color as selected by DEN Project Manager

PART 3 EXECUTION

3.01 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Inspect field-insulated equipment, randomly selected by DEN Project Manager, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to one location for each type of equipment defined in the “Equipment Insulation Schedule” Article. For large equipment, remove only a portion adequate to determine compliance.

B. All insulation applications will be considered defective Work if sample inspection reveals noncompliance with requirements.

Section 220719: Plumbing Piping Insulation

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.

1. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.
2. Detail attachment and covering of heat tracing inside insulation.
3. Detail insulation application at pipe expansion joints for each type of insulation.
4. Detail insulation application at elbows, fittings, flanges, valves, and specialties for each type of insulation.
5. Detail removable insulation at piping specialties, equipment connections, and access panels.
6. Detail application of field-applied jackets.
7. Detail application at linkages of control devices.

B. Samples: Coordinate sample requirements with DEN Project Manager. For each type of insulation and jacket indicated. Identify each Sample, describing product and intended use. Sample sizes are as follows:

1. Preformed Pipe Insulation Materials: 12 inches long by NPS 2.
2. Jacket Materials for Pipe: 12 inches long by NPS 2
3. Sheet Jacket Materials: 12 inches square.
4. Manufacturer's Color Charts: For products where color is specified, show the full range of colors available for each type of finish material.

1.02 QUALITY ASSURANCE

A. Verify mockup requirements with DEN Project Manager.

B. Mockups: Before installing insulation, build mockups for each type of insulation and finish listed below to demonstrate quality of insulation application and finishes. Build mockups in the location indicated or, if not indicated, as directed by DEN Project Manager. Use materials indicated for the completed Work.

1. Piping Mockups:
   a. One 10-foot section of NPS 2 straight pipe.
   b. One each of a 90-degree threaded, welded, and flanged elbow.
   c. One each of a threaded, welded, and flanged tee fitting.
   d. One NPS 2or smaller valve, and one NPS 2-1/2 or larger valve.
   e. Four support hangers including hanger shield and insert.
   f. One threaded strainer and one flanged strainer with removable portion of insulation.
   g. One threaded reducer and one welded reducer.
   h. One pressure temperature tap.
   i. One mechanical coupling.
2. For each mockup, fabricate cutaway sections to allow observation of application details for insulation materials, adhesives, mastics, attachments, and jackets.
3. Notify DEN Project Manager seven (7) days in advance of dates and times when mockups will be constructed.
4. Obtain DEN Project Manager's approval of mockups before starting insulation application.
5. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless DEN Project Manager specifically approves such deviations in writing.
6. Maintain mockups during construction in an undisturbed condition as a standard for judging the completed Work.
7. Demolish and remove mockups when directed.

PART 2 PRODUCTS

2.01 FIELD-APPLIED JACKETS

A. Color: Color-code PVC jackets based on system. Color as selected by DEN Project Manager.

PART 3 EXECUTION

3.01 FINISHES

A. Color: Final paint color as selected by DEN Project Manager. Vary first and second coats to allow visual inspection of the completed Work

3.02 INSTALLATION OF FIELD-APPLIED JACKETS

A. Indoor, Concealed Applications: Insulated pipes conveying fluids above ambient temperature shall have standard jackets, with vapor barrier, factory-applied or field-applied. Insulate fittings, joints, and valves with insulation of like material and thickness as adjoining pipe, and finish with glass cloth and adhesive. PVC jackets may be used if in accordance with specified flame spread and smoke developed limitations.

B. Indoor, Exposed Applications: For pipe exposed in mechanical equipment rooms or in finished spaces, insulate as for concealed applications. Finish with PVC jackets color-coded to match system-colors below are DEN standard but need to be verified with Project Manager:

1. Domestic Cold Water – Green
2. Domestic Hot Water – Red
3. Domestic Recirculating Water – Red
4. Non-Potable Water – Yellow

3.03 FIELD QUALITY CONTROL

A. Inspect pipe, fittings, strainers, and valves, randomly selected by DEN Project Manager, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to three locations of straight pipe, three locations of threaded fittings, three locations of welded fittings, two locations of threaded strainers, two locations of welded strainers, three locations of threaded valves, and three locations of flanged valves for each pipe service defined in the "Piping Insulation Schedule, General", "Indoor Piping Insulation Schedule", and "Outdoor, Aboveground Piping Insulation Schedule" Articles.

B. All insulation applications will be considered defective Work if sample inspection reveals noncompliance with requirements.

Section 221113: Facility Water Distribution Piping

PART 1 GENERAL

1.01 QUALITY ASSURANCE

A. Product Options: Drawings indicate size, profiles, and dimensional requirements of piping and specialties and are based on the specific system indicated. Refer to Division 01 Section "Product Requirements."

1.02 COORDINATION

A. Coordinate connection to water main with Denver Water Department.

PART 2 PRODUCTS

2.01 COPPER TUBE AND FITTINGS

A. Soft Copper Tube: ASTM B 88, Type K, water tube, annealed temper.

1. Copper, Solder-Joint Fittings: ASME B16.18, cast-copper-alloy or ASME B16.22, wrought-copper, solder-joint pressure type.

B. Hard Copper Tube: ASTM B 88, Type L, water tube, drawn temper.

1. Copper, Solder-Joint Fittings: ASME B16.18, cast-copper-alloy or ASME B16.22, wrought-copper, solder-joint pressure type.

C. Bronze Flanges: ASME B16.24, Class 150, with solder-joint end. Furnish Class 300 flanges if required to match piping.

D. Copper Unions: MSS SP-123, cast-copper-alloy, hexagonal-stock body with ball-and-socket, metal-to-metal seating surfaces, and solder-joint or threaded ends.

E. Push-on or press-on types of copper connectors are not allowed.

2.02 DUCTILE-IRON PIPE AND FITTINGS

A. Mechanical-Joint, Ductile-Iron Pipe: AWWA C151, with mechanical-joint bell and plain spigot end unless flanged ends are indicated.

1. Mechanical-Joint, Ductile-Iron Fittings: AWWA C110, ductile- or gray-iron standard pattern or AWWA C153, ductile-iron compact pattern.
2. Glands, Gaskets, and Bolts: AWWA C111, ductile- or gray-iron glands, rubber gaskets, and steel bolts.

B. Push-on-Joint, Ductile-Iron Pipe: AWWA C151, with push-on-joint bell and plain spigot end unless flanged ends are indicated.

1. Push-on-Joint, Ductile-Iron Fittings: AWWA C110, ductile- or gray-iron standard pattern or AWWA C153, ductile-iron compact pattern.
2. Gaskets: AWWA C111, rubber.

C. Flanges: ASME 16.1, Class 125, cast iron.

Verify requirements with the Denver Water Engineering Standards.

2.03 PE PIPE AND FITTINGS

A. PE, ASTM Pipe: ASTM D 2239, SDR No. 9; with PE compound number required to give pressure rating not less than 200 psig.

1. Insert Fittings for PE Pipe: ASTM D 2609, made of PA, PP, or PVC with serrated male insert ends matching inside of pipe. Include bands or crimp rings.
2. Molded PE Fittings: ASTM D 3350, PE resin, socket- or butt-fusion type, made to match PE pipe dimensions and class.

B. PE, AWWA Pipe: AWWA C906, DR No. 9, or 9.3; with PE compound number required to give pressure rating not less than 200 psig.

1. PE, AWWA Fittings: AWWA C906, socket- or butt-fusion type, with DR number matching pipe and PE compound number required to give pressure rating not less than 200 psig.

2.04 PVC PIPE AND FITTINGS

A. Schedule 80 pipe and fittings only unless written permission from DEN Mechanical Engineer to use other schedules.

B. PVC pipe and fittings above ground not allowed without

C. written permission from DEN Mechanical Engineer.

D. PVC domestic water piping is not allowed at the Terminal Complex.

E. PVC, Schedule 80 Pipe: ASTM D 1785.

1. PVC, Schedule 80 Socket Fittings: ASTM D 2467.
2. PVC, Schedule 80 Threaded Fittings: ASTM D 2464.

F. PVC, AWWA Pipe: AWWA C900, Class 150, with bell end with gasket, and with spigot end.

1. PVC Fabricated Fittings: AWWA C900, Class 150, with bell-and-spigot or double-bell ends. Include elastomeric gasket in each bell.
2. PVC Molded Fittings: AWWA C907, Class 150, with bell-and-spigot or double-bell ends. Include elastomeric gasket in each bell.

2.05 FIBERGLASS PIPE AND FITTINGS

A. Fiberglass pipe and fittings only unless written permission from DEN Mechanical Engineer.

B. AWWA RTRP: AWWA C950, Class 150, Type I, Grade 1, epoxy, with bell-and-spigot ends for bonded joints.

1. RTRF: AWWA C950, similar to pipe in material, pressure class, and joining method.

C. UL RTRP: UL 1713, Class 150, with bell-and-spigot ends with gasket or seal for gasketed joints.

1. RTRF: Similar to pipe in material, pressure class, and joining method.

PART 3 EXECUTION

3.01 PIPING APPLICATIONS

A. Underground water-service piping NPS 3/4 to NPS 3 shall be any of the following:

1. Soft copper tube with wrought-copper, solder-joint fittings with brazed joints. Avoid joints in underground piping to the greatest degree possible.
2. PE, ASTM pipe; molded PE fittings; and heat-fusion joints.
3. PVC, Schedule 80 pipe; PVC, Schedule 80 socket fittings; and solvent-cemented joints.

B. Underground water-service piping NPS 4 to NPS 8 shall be any of the following:

1. Soft copper tube, wrought-copper, solder-joint fittings, with brazed joints. Avoid joints in underground piping to the greatest degree possible.
2. Ductile-iron, push-on-joint pipe; ductile-iron, push-on-joint fittings; and gasketed or mechanical-joint pipe; ductile-iron, mechanical-joint fittings; and mechanical joints.
3. PE, AWWA pipe; PE, AWWA fittings; and heat-fusion joints.
4. PVC, Schedule 80 pipe; PVC, Schedule 80 socket fittings; and solvent-cemented joints
5. NPS 4 and NPS 6: PVC, AWWA Class 150 pipe; PVC, AWWA Class 150 fabricated or molded fittings; and gasketed joints.

C. Aboveground water-service piping NPS 2 and smaller shall be the following:

1. Hard copper tube, Type L; wrought-copper, solder-joint fittings; and soldered joints.

D. Aboveground water-service piping NPS 2-1/2 to NPS 8 shall be any of the following:

1. Hard copper tube, wrought-copper, solder-joint fittings; and brazed joints.
2. Fiberglass, AWWA RTRP, Class 150; RTRF; and bonded joints.

Section 221116: Domestic Water Piping

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Contractor shall submit fully dimensioned spool drawings for all welded piping work. Drawings shall indicate all weld types, sizes, and materials to be used. The spool drawing size shall match the full-size contract documents of either 24x36 or 34x44. Spool drawings shall be submitted in either the latest version of AutoCAD (dwg) or the latest version of Adobe Acrobat (pdf). Adobe Acrobat files shall not contain security. Other file formats will not be accepted.

1.02 INFORMATIONAL SUBMITTALS

A. Pneumatic Leak Test for water systems:

1. Contractor shall submit drawings and procedures of the pneumatic leak test to the DEN Mechanical Engineer no later than two (2) weeks prior to testing. Contractor may not proceed with tests unless approved in writing by the DEN Mechanical Engineer or DEN Mechanical Inspector.

B. Disinfection and other Field Test Reports: Written reports of tests specified in Part 3 of this Section. Include the following:

C. Test procedures used.

D. Test results that comply with requirements.

E. Failed test results and corrective action taken to achieve requirements

PART 2 PRODUCTS

2.01 PIPING MATERIALS

A. PEX tube and fittings are not allowed without written permission from DEN Mechanical Engineer.

B. Galvanized pipe and fittings are not allowed without written permission from DEN Mechanical Engineer.

2.02 COPPER TUBE AND FITTINGS

A. Soft Copper Tube: ASTM B 88, Type K, water tube, annealed temper.

B. Hard Copper Tube: ASTM B 88, Type L, water tube, drawn temper.

C. Push-on or press-on types of connectors are not allowed.

2.03 CPVC PIPING

A. CPVC pipe and fittings above ground not allowed without written permission from DEN Mechanical Engineer.

B. CPVC domestic water piping is not allowed at the Terminal Complex.

C. CPVC Pipe: ASTM F 441/F 441M, Schedule 80, plenum-rated.

1. CPVC Socket Fittings: ASTM F 439 for Schedule 80, plenum-rated.
2. CPVC Threaded Fittings: ASTM F 437, Schedule 80, plenum rated.

2.04 PVC PIPING

A. Schedule 80 pipe and fittings only unless written permission from DEN Mechanical Engineer to use other schedules.

B. PVC pipe and fittings above ground not allowed without

C. written permission from DEN Mechanical Engineer.

D. PVC domestic water piping is not allowed at the Terminal Complex.

E. PVC Pipe: ASTM D 1785, Schedule 80, plenum-rated.

1. PVC Socket Fittings: ASTM D 2467 for Schedule 80, plenum-rated.

2. PVC Schedule 80 Threaded Fittings: ASTM D 2464, plenum-rated.

PART 3 EXECUTION

3.01 FIELD QUALITY CONTROL

A. Perform the following inspections:

1. Piping Inspections:
   a. Do not enclose, cover, or put piping into operation until it has been inspected and approved by authorities having jurisdiction.
   b. During installation, notify authorities having jurisdiction at least one day before inspection must be made. Perform tests specified below in presence of authorities having jurisdiction:
      1. Roughing-in Inspection: Arrange for inspection of piping before concealing or closing in after roughing in and before setting fixtures.
      2. Final Inspection: Arrange for authorities having jurisdiction to observe tests specified in “Piping Tests” Subparagraph below and to ensure compliance with requirements.
   c. Reinspection: If authorities having jurisdiction find that piping will not pass tests or inspections, make required corrections, and arrange for reinspection.
   d. Reports: Prepare inspection reports and have them signed by authorities having jurisdiction.

B. Perform the Following Piping Tests:

1. Perform all tests in the presence of the authorized City representative when required. Contractor shall provide inspector 48-hour prior notice of test; also notify DEN Project Manager.
2. Hydrostatic Leak Test:
   a. Perform hydrostatic leak test on all piping systems prior to making final connections to fixtures and equipment.
   b. Hydrostatic Leak Test Procedure:
      1. Leak test procedures shall comply with ASME B31.9.
      2. Fill piping systems with clear water, vent all air, and pressurize at 150% of operating pressure, (but not less than 100 psi or more than the pipe rating pressure) for 15 minutes. Test fails if leakage is observed, or pressure drop exceeds 5% of test pressure.
3. No piping or joint shall be left untested. All leaks shall be repaired, and the piping system shall be re-tested until satisfactory results are obtained.
4. Pneumatic Leak Test:
   a. General: Pneumatic leak tests shall only be used on piping with restricted access, piping exposed to freezing conditions, or where water leakage would damage critical DEN operational equipment.
      1. Contractor shall submit a written request for testing.
   b. Pneumatic Test Procedure:
      1. Contractor shall submit safety plan for pneumatic testing prior to test.
      2. General: Compressed gas poses the risk of sudden release of stored energy. For that reason, pneumatic testing shall be used only within the following limitations:
         a. The piping system does not contain cast iron pipe or plastic pipe subject to brittle failure.
         b. The system does not contain soldered or solvent cement joints over NPS 2.
         c. The test pressure does not exceed 150 psig.
      3. Test Medium: The gas shall be nonflammable and nontoxic.

4. Preliminary Test: Prior to application of full pneumatic test pressure, a preliminary test of not more than 10 psig shall be applied to reveal possible major leaks. Pneumatic test pressure is as follows:
   a. Except as limited in Subparagraph b below, the test pressure shall not exceed 1.25 times the design pressure. Pressure shall be applied in several stages, allowing time for the system to reach equilibrium at each stage.
   b. The test pressure shall not exceed the maximum allowable pneumatic test pressure for any vessel, pump, valve, or other component in the system under test.
5. Examination for Leakage: After the preliminary test, pressure shall be raised in stages of not more than 25% up to full pneumatic test pressure, allowing time for equalization of strains and detection of major leaks at each stage. Following the application of test pressure for at least 10 minutes, the pressure may be reduced to design pressure and examination shall be made for leakage of the piping. Leaks may be detected by soap bubble, halogen gas, scented gas, test gage monitoring, ultrasonic, or other suitable means. If leaks are found, pressure shall be vented, appropriate repair or replacement shall be made, and the pneumatic test repeated until no leakage is found.
6. Contractor shall measure the surface temperature of the pipe for the duration of testing. The pneumatic test will be deemed successful only when the test pressure can be held at a constant pipe surface temperature for a period of no less than 10 continuous minutes. Record of the pipe temperatures and pressures during the duration of the test shall be submitted to the DEN Project Manager following completion of the test.

5. Testing shall be witnessed by DEN Mechanical Inspector and DEN Project Manager or Designated Representative.
6. Repair piping systems which fail required piping test, by disassembly and reinstallation, using new materials to extent required to overcome leakage. Do not use chemicals, stop-leak compounds, mastics, or other temporary repair methods.
7. Drain test water from piping systems after testing and repair work that has been completed.
8. Prepare written report of testing procedures and result.

3.02 PIPING SCHEDULE

A. Under building slab, domestic water piping NPS 4 and smaller shall be any of the following:

1. Soft copper tube, wrought-copper, solder-joint fittings with brazed joints. Avoid joints in underground piping to the greatest degree possible.

B. Aboveground domestic water piping NPS 2 and smaller shall be any of the following:

1. Hard copper tube, wrought-copper, solder-joint fittings; and soldered joints. Fitting Option: Extruded-tee connections and brazed joints may be used on aboveground copper tubing.

C. Aboveground domestic water piping NPS 2-1/2 to NPS 8 shall be any of the following:

1. Hard copper tube, Type L; wrought-copper, solder-joint fittings; and brazed joints. Fitting Option: Extruded-tee connections and brazed joints may be used on aboveground copper tubing.
2. CPVC Piping with Socket or threaded type fittings.
3. PVC Piping with Socket or threaded type fittings.

3.03 VALVE SCHEDULE

A. Shutoff Duty: Use ball valves for piping NPS 2 and smaller. Use butterfly, or ball valves with flanged ends for piping NPS 2-1/2 and larger.

B. Throttling Duty: Use ball or globe valves for piping NPS 2 and smaller. Use butterfly or ball valves with flanged ends for piping NPS 2-1/2 and larger.

C. Hot-Water Circulation Piping, Balancing Duty: Calibrated balancing valves.

D. Drain Duty: Hose-end drain valves.

Section 221119: Domestic Water Piping Specialties

PART 1 GENERAL

1.01 CLOSEOUT SUBMITTALS

A. Extra Materials

Extra stock materials may not be allowed on publicly funded projects. Coordinate extra stock submittal requirements with DEN Project Manager.

1. Provide two (2) each of loose keys and hose end vacuum breakers.
2. Water Filter Cartridges: Provide two (2) or 10% of amount installed, whichever is greater, for each type and size indicated.

PART 2 PRODUCTS

2.01 WATER-HAMMER ARRESTERS

1. Type: Provide in all stainless steel construction, metal-bellows type with pressurized metal cushioning chamber, precharged, suitable for operation in temperature range-100 to +300 degrees F and maximum 250 psig working pressure.

Note: Tenant Water and BTU Meters to be on IE Dedicated Engine. See Communications and Electronic Systems DSM for more networking requirements.

2.02 TERMINAL COMPLEX TENANT FLOW (WATER) METERS

A. General Requirements for Flow (Water) Meters:

1. Meters are sub-meters used primarily by Tenants using water supplied from piping with-in the building.
2. Adjustable for changes in system operational parameters.
3. Liquid Sensors, Meters, and Transmitters: Extended range of 10 percent above Project design flow and 10 percent below Project minimum flow to signal abnormal flow conditions.
4. Manufacturer shall certify that each flow instrument indicated complies with specified performance requirements and characteristics.
5. Product certificates are required.
6. All devices shall have a BACnet MSTP fieldbus interface.

B. Insertion Turbine Flow Meter:

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Onicon Incorporated F-1100 Series Sensor with D-100 Series Remote Display Module for pipe sizes NPS 1-1/4 to NPS 2
   b. Onicon F-1200 Series Sensor with D-100 Series Remote Display Module for pipe sizes NPS 2-1/2 and larger.
2. Description:
   a. Operating pressure of 300 psig with a temperature of 200 deg F.

b. Meters in hot water systems shall be suitable for maximum system temperatures encountered, but not less than 250 deg F.

c. Pressure drop not to exceed 1 psig at 20-fps flow velocity in a NPS 2 pipe and decreasing in large pipe with lower velocity.

d. Sensor Accuracy:

1. Within 1 percent of actual flow between the flow velocity range of 3 to 30 fps.
2. Within 2 percent of actual flow between the flow velocity range of 0.4 to 20 fps.
3. Within 0.5 percent of actual reading at the calibrated velocity.

e. Wet calibrate and tag sensors to standards traceable to NIST, and provide each sensor with a certificate of calibration.

3. Sensor:

a. For Pipe Sizes NPS 2 and Smaller: Single turbine sensors.

b. For Pipe Sizes NPS 2-1/2 and Larger: Dual turbine sensors.

c. Piping with Bi-directional Flow: Bi-directional dual turbine sensors.

d. Dual turbine sensors shall have dual, contra-rotating turbine elements, each turbine element with its own rotational sensing system, and an averaging circuit.

e. Rotational sensing of each turbine shall be accomplished electronically by sensing electronic impedance change (non-magnetic and non-photoelectric).

f. Sensor shall have an integral frequency output linear with flow rate. For dual turbine units, with individual top and bottom turbine outputs for diagnostic purposes.

g. Bi-directional sensors shall have isolated solid-state dry contacts with a contact rating of 100 mA at 50 V. The contacts shall close when the flow in direction of arrow is 0.18 fps or more.

h. Flow sensor shall be complete with installation hardware necessary to enable insertion and removal from pipe without system shutdown.

i. Construct turbine elements of polypropylene with sapphire jewel bearings and tungsten carbide shafts. Construct wetted metal components of Type 316 stainless steel, including installation hardware.

j. House sensor electronics in a NEMA 250, Type 4 enclosure.

k. Enclosure shall include connection(s) for field-installed conduit.

l. Sensor shall have cable of length sufficient to connect to display module.

m. Sensor housing shall have full port ball valve for system isolation.

4. Display Module:

a. Remote from sensor.

b. House in a NEMA 250, Type 4X enclosure.

c. Label terminal strip for all wiring connections.

d. 120-V ac power supply with 24-V dc output to power the flow sensor.

e. Remote Interface:

1. Hardwired Analog Outputs for Flow Rate and Totalization: 4 to 20 mA and zero- to 10-V dc.
2. Outputs linear to within 0.1 percent of calibrated span.

f. Digital display for flow rate and totalized flow.

1. At least eight display digits for totalization.
2. Bi-directional units with separate digital display for flow and totalization in each direction.

g. Local reset of flow totalization.

h. Program and data shall be stored in nonvolatile memory in event of power loss.

i. For bi-directional units, with display of flow direction (contacts open or closed).

C. Inline Turbine Flow Meter:

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Onicon Incorporated; F-1300 Series Sensor with D-100 Series Remote Display Module.
2. Description:
   a. Available in NPS 3/4 and NPS 1.
   b. Operating pressure of 300 psig with a temperature of 200 deg F.
   c. Meters in hot water systems shall be suitable for maximum system temperatures encountered, but not less than 250 deg F.
   d. Pressure drop not to exceed 3 psig at 38 gpm.
   e. Sensor Accuracy:
      1. Within 2 percent of actual flow between the flow range of 0.8 to 38 gpm.
      2. Within 0.5 percent of actual reading at the calibrated velocity.
   f. Wet calibrate and tag sensors to standards traceable to NIST, and provide each sensor with a certificate of calibration.
3. Sensor:
   a. Rotational sensing of turbine shall be accomplished electronically by sensing electronic impedance change (non-magnetic and non-photoelectric).
   b. Sensor shall have an integral frequency output linear with flow rate.
   c. Sensor shall have threaded union on each end.
   d. Construct turbine elements of polypropylene with sapphire jewel bearings and tungsten carbide shafts.
   e. Construct wetted metal components of brass or stainless steel.
   f. House sensor electronics in a NEMA 250, Type 4 enclosure.
   g. Enclosure shall include connection(s) for field-installed conduit.
   h. Sensor shall have cable of length sufficient to connect to display module.
4. Display Module:
   a. Remote from sensor.
   b. Enclosure: NEMA 250, Type 4X.
   c. Label terminal strip for all wiring connections.
   d. 120-V ac power supply with 24-V dc output to power the flow sensor.
   e. Remote Interface:
      1. Hardwired Analog Outputs for Flow Rate and Totalization: 4 to 20 mA and zero- to 10-V dc.
      2. Outputs linear to within 0.1 percent of calibrated span.
   f. Digital display of flow rate and totalized flow.
   g. At least eight display digits for totalization.
   h. Local reset of flow totalization.
   i. Program and data shall be stored in nonvolatile memory in the event of power loss.

D. In-line Body Electromagnetic Flow Meter:

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Onicon Incorporated; FT-3000 Series with D-100 Series remote display module.
2. Description:
   a. No moving parts.

b. Suitable for flow measurement of fluids with electrical conductivity more than 5 microsiemens per cm.

c. Inherent bi-directional flow measurement.

d. Flow measurement with three pipe diameters upstream and two pipe diameters downstream.

e. Wet calibrate and tag meters to standards traceable to NIST, and provide each meter with a certificate of calibration.

f. Transmitter remote from meter.

3. Performance:

a. Accuracy for Velocities between 3.3 and 33 fps: Within 0.2 percent of reading.

b. Accuracy for Velocities between 1.0 and 3.3 fps: Within 0.75 percent of reading.

c. Accuracy for Velocities Less than 1.0 fps: Within 0.0075 fps.

d. Ambient Temperature: Minus 4 to plus 140 deg F.

e. Process Temperature: Minus 4 to 212 deg F.

f. Pressure: 225 psig.

4. Analog Output Current Signal:

a. Two-wire, 4- to 20-mA dc current source.

b. Signal capable of operating into 1000-ohm load.

c. Isolated.

5. Digital Output Signal: Two, programmable, digital/pulse outputs configurable for frequency, pulse, or directional flow.

6. Display Module:

a. Remote from sensor.

b. House in a NEMA 250, Type 4X enclosure.

c. Label terminal strip for all wiring connections.

d. 120-V ac power supply with 24-V dc output to power the flow sensor.

e. Remote Interface:

1. Hardwired Analog Outputs for Flow Rate and Totalization: 4 to 20 mA and zero- to 10-V dc.

2. Outputs linear to within 0.1 percent of calibrated span.

f. Digital display for flow rate and totalized flow.

1. At least eight display digits for totalization.

2. Bi-directional units with separate digital display for flow and totalization in each direction.

g. Local reset of flow totalization.

h. Program and data shall be stored in nonvolatile memory in event of power loss.

i. For bi-directional units, with display of flow direction (contacts open or closed).

7. Operator Interface:

a. Keypad.

b. Digital Display: Multiple-line digital display of alphanumerical characters.

c. LED for normal and alarm operation.

8. Construction:

a. Body: Epoxy-coated carbon steel or Type 316 stainless steel.

b. Body Liner Material: PTFE.

c. Flow Tube: Type 304 stainless steel.

d. Connection: 150 Class flange.

e. Electrodes: Type 316 stainless steel. Quantity determined by manufacturer based on application.

f. Electronics Enclosure:

1. Painted aluminum.
2. Removable cover.
3. NEMA 250, Type 6.

E. Insertion Electromagnetic Flow Meter:

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Onicon Incorporated; F-3500 Series with D-100 Series remote display module.
2. Description:
   a. No moving parts.
   b. Suitable for flow measurement of fluids with electrical conductivity between 20 to 60000 microsiemens per centimeter.
   c. Suitable for pipe sizes NPS 3 through NPS 72.
   d. Wet calibrate and tag meters to standards traceable to NIST, and provide each meter with a certificate of calibration.
   e. Continuous auto-zero function.
   f. Transmitter integral to meter.
3. Performance:
   a. Flow Range: 0.25 to 20 fps
   b. Accuracy for Velocities between 2 and 20 fps: Within 1 percent of reading.
   c. Accuracy for Velocities Less than 2 fps: Within 0.02 fps.
   d. Ambient Temperature: Minus 5 to 150 deg F.
   e. Process Temperature: 15 to 250 deg F.
   f. Pressure: 400 psig.
4. Output Signals:
   a. Field-selectable analog signals.
      1. Current Signal (Isolated): 4 to 20 mA.
      2. Voltage Signal (Isolated): Zero- to 10-V dc.
   b. Digital Signal: Dry-contact closure signaling fault condition.
   c. Frequency Signal: Zero- to 15-V peak pulse, zero to 500 Hz.
   d. Scalable Pulse Output:
      1. Isolated solid-state dry contact.
      2. Contact Rating: 100 mA at 50-V dc.
      3. Pulse Duration: 0.5, 1, 2, or 6 seconds.
5. Construction:
   a. Wetted Metal Parts: Type 316 stainless steel.
   b. Sensor Head: Polysulfone.
   c. Process Connection: 1-inch.
   d. Instrument Isolation Valve: Full port Type 316 stainless-steel ball valve for system isolation.
   e. Electrodes: Type 316 stainless steel.
   f. Electronics Enclosure:
      1. Painted aluminum.
      2. Removable cover.
      3. NEMA 250, Type 4.

4. Electrical Connection: PVC-jacketed cable, 10 feet long.
5. Conduit Connection: 1/2-inch trade size.

6. Display Module:
   a. Remote from meter.
   b. House in a NEMA 250, Type 4X enclosure.
   c. Label terminal strip for all wiring connections.
   d. 120-V ac power supply with 24-V dc output to power the flow sensor.
   e. Input Signal from Meter: Zero- to 15-V pulse output.
   f. Output Signals: Additional output signals furnished with flow meter connected to display module terminal strip.
   g. Auxiliary Output Signals: Analog current output (isolated) shall be 4 to 20 mA.
   h. Digital Display:
      1. Flow rate.
      2. Totalized flow.
      3. At least six display digits for flow rate and eight display digits for totalization.
      4. Bi-directional units with separate digital display for flow and totalization in each direction.
   i. Local reset of flow totalization.
   j. Program and data shall be stored in nonvolatile memory in the event of power loss.
   k. For bi-directional units, provide LED display of flow direction (contacts open or closed).

PART 3 EXECUTION

3.01 ELECTRIC POWER

A. Furnish and install electrical power to products requiring electrical connections.

B. Furnish and install circuit breakers. Comply with requirements in Section 262816 “Enclosed Switches and Circuit Breakers.”

C. Furnish and install power wiring. Comply with requirements in Section 260519 “Low-Voltage Electrical Power Conductors and Cables.”

D. Furnish and install raceways. Comply with requirements in Section 260533 “Raceways and Boxes for Electrical Systems.”

3.02 INSTRUMENT APPLICATIONS

A. Select from instrument types to achieve performance requirements and characteristics indicated while subjected to full range of system operation encountered.

B. Flow Meters:

1. Potable Water System: Turbine flow meter or Electromagnetic flow meter.

C. Mounting Location:

1. Rough-in: Outline instrument-mounting locations before setting instruments and routing cable, wiring, tubing, and conduit to final location.

D. Mounting Height:

1. Mount instruments in user-occupied space to match mounting height of light switches unless otherwise indicated on Drawings. Mounting height shall comply with codes and accessibility requirements.
2. Mount switches and transmitters, located in mechanical equipment rooms and other similar space not subject to code, state, and federal accessibility requirements, within a range of 42 to 72 inches above the adjacent floor, grade, or service catwalk or platform.

a. Make every effort to mount at 60 inches.

E. Identify system components, wiring, cabling, and terminals. Each piece of wire, cable, and tubing shall have the same designation at each end for operators to determine continuity at points of connection. Comply with requirements for identification specified in Section 260553 “Identification for Electrical Systems.”

F. Install engraved phenolic nameplate with instrument identification and on face of ceiling directly below instruments concealed above ceilings.

3.03 FLOW INSTRUMENTS INSTALLATION

A. Liquid Flow Meters:

1. Install meters in straight sections of piping with manufacturer-recommended straight piping upstream and downstream of sensor.
2. Install pipe reducers for in-line meters smaller than line size. Install reducers at distance from meter to avoid interference and impact on accuracy.
3. Install in-line meters with flanges or unions to provide drop-in and-out installation.
4. Insertion Meters:
   a. Install system process connections full size of meter connection, but not less than NPS 1 (DN 25) (DN 40) (DN 50). Provide bushing if required to mate to system connection.
   b. Install meter in top dead center of horizontal pipe positioned in an accessible location to allow for inspection and replacement.
   c. In applications where top-dead-center location is not possible due to field constraints, install meter at location along top half of pipe if acceptable by manufacturer for mounting orientation.

B. Transmitters:

   a. Install liquid flow transmitters, not integral to sensors, in vicinity of sensor. Where multiple flow transmitters serving same system are located in same room, co-locate transmitters by system to provide service personnel a single and convenient location for inspection and service.

3.04 FIELD QUALITY CONTROL

A. Flow Instrument Checkout:

1. Verify that sensors are installed correctly with respect to flow direction.
2. Verify that sensor attachment is properly secured and sealed.
3. Inspect instrument tag against approved submittal.
4. Verify that recommended upstream and downstream distances have been maintained.

3.05 ADJUSTING

A. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.

B. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.

C. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.

D. Equipment and procedures used for calibration shall meet instrument manufacturer's recommendations.

E. Provide diagnostic and test equipment for calibration and adjustment.

F. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. For example, an installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.

G. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.

H. If after-calibration-indicated performance cannot be achieved, replace out-of-tolerance instruments.

I. Analog Signals:

1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.
3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistant source.

J. Digital Signals:

1. Check digital signals using a jumper wire.
2. Check digital signals using an ohmmeter to test for contact.

K. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.

L. Transmitters:

1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.

Section 221123: Domestic Water Pumps

PART 1 GENERAL

1.01 EXTRA MATERIALS

Extra materials may not be allowed for publicly funded projects. Coordinate extra stock requirements with DEN Project Manager.

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Mechanical Seals: One (1) set mechanical seal(s) for each pump.

PART 2 PRODUCTS

2.01 GENERAL

A. Statically and dynamically balance rotating parts.

B. Construction to permit complete servicing without breaking piping or motor connections.

C. Pumps to operate at nominal 1750 rpm unless specified otherwise.

D. Pump connections to be flanged.

PART 3 EXECUTION

3.01 INSTALLATION

A. Engage a qualified millwright to check, align, and certify separately coupled pumps prior to start-up.

Section 221123.13: Domestic-Water Packaged Booster Pumps

PART 1 GENERAL

1.01 QUALITY ASSURANCE

A. Perform Work in accordance with Denver codes and standards.

B. Provide pumps with manufacturer's name, model number, and rating/capacity identified.

C. Source Limitations: Obtain hydronic pumps through one source from a single manufacturer.

1.02 EXTRA MATERIALS

Extra materials may not be allowed for publicly funded projects. Coordinate extra stock requirements with DEN Project Manager.

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Mechanical Seals: One (1) set mechanical seal(s) for each pump.

PART 2 PRODUCTS

2.01 GENERAL

A. Statically and dynamically balance rotating parts.

B. Construction to permit complete servicing without breaking piping or motor connections.

C. Pumps to operate at nominal 1750 rpm unless specified otherwise.

D. Pump connections to be flanged.

E. Variable Frequency Controllers:

1. Proportional Integral Derivative (PID) control interface.
2. ASHRAE 135 DDC System for HVAC Protocols for Network Communications.
3. Line Conditioning:
   a. Input line conditioning.
   b. Output filtering.
   c. EMI/RFI filtering.

F. Building Automation System Interface: Provide auxiliary contacts for interface to BACnet building automation system. Building automation systems are specified in Section 230900 “Instrumentation and Control for HVAC.” Include the following:

1. On-off status of pump.
2. Alarm status.
3. High-suction-pressure cutout.
4. Low-discharge-pressure cutout.
5. High-discharge-pressure cutout.

PART 3 EXECUTION

3.01 INSTALLATION

A. Engage a qualified millwright to check, align, and certify separately coupled pumps prior to start-up.

3.02 FIELD QUALITY CONTROL

A. Perform tests and inspections.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

Section 221313: Facility Sanitary Sewers

PART 1 GENERAL

PART 2 PRODUCTS

2.01 GENERAL

A. No cast Iron pipe or fittings allowed below grade or slabs.

PART 3 EXECUTION

3.01 PIPING INSTALLATION

A. General: Install piping and clean-outs in accordance with the Denver Wastewater Management standards, specifications, and as per the standard detail drawings.

B. All piping below concrete slabs, apron or roadways shall be incased in flowable backfill.

C. Minimum Cover:

1. For airside sewer systems subject to aircraft loading on rigid pavement, a minimum depth of cover of 1.50 feet, measured from the bottom of the slab is required. If there is any discrepancy, the contractor should contact DEN Project Manager and correct the discrepancy before installation.

3.02 FIELD QUALITY CONTROL

A. Inspection:

1. The facility sewer system shall be inspected by the Contractor's Quality Control Inspector. A record of the inspection including any defects or deviations from the contract shall be submitted to the DEN Project Manager. Any observable defects shall be corrected promptly by the Contractor.
2. Inspect interior of piping to determine whether line displacement or other damage has occurred. Inspect after approximately 24 inches of backfill is in place, and again at completion of Project.
   a. Submit separate report for each system inspection.
   b. Defects requiring correction include the following:
      1. Alignment: Less than full diameter of inside of pipe is visible between structures.
      2. Deflection: Flexible piping with deflection that prevents passage of ball or cylinder of size not less than 92.5 percent of piping diameter.
      3. Damage: Crushed, broken, cracked, or otherwise damaged piping.
      4. Infiltration: Water leakage into piping.
      5. Exfiltration: Water leakage from or around piping.
   c. Replace defective piping using new materials, and repeat inspections until defects are within allowances specified.
   d. Reinspect and repeat procedure until results are satisfactory.

B. Testing: Contractor's inspection and testing agency shall perform testing of completed piping in accordance with Section 9.00 of the Denver Wastewater Management Division Technical Specifications. The following tests shall be performed on the piping system:

Test:	System Type:
Exfiltration Test-	All systems.
Deflection Test-	Only plastic piping.
Infiltration Test-	Only in case of excessive ground water.

Section 221316: Sanitary Waste and Vent Piping

PART 1 GENERAL

1.01 INFORMATIONAL SUBMITTALS

A. Contractor shall submit fully dimensioned spool drawings for all welded piping work. Drawings shall indicate all weld types, sizes, and materials to be used. Provide drawings in electronic format in compliance with Division 01 requirements and currently accepted by DEN.

PART 2 PRODUCTS

2.01 GENERAL

A. No cast Iron pipe or fittings allowed below grade or slabs.

B. Plastic piping shall not be used inside the building above grade without written permission of the DEN Mechanical Engineer.

2.02 SPECIAL PIPE FITTINGS

A. PVC Flexible Expansion Joints:

1. Basis of design: FLEX-TEND DWV Flexible Expansion Joint by EBAA Iron Sales, Inc.
2. Description: Compound, PVC fitting with End connection O.D. that are compatible with ASTM D1785/D2665 and F891 PVC pipe and are to be solvent welded. Adapters are needed for transitioning to ASTM D3034 pipe O.D. Include two ball-joint sections and one or more sleeve sections.
   a. Polyethylene sleeve is to be provided to minimize soil friction and allow the unit to move more freely. (1725 kPa).

PART 3 EXECUTION

3.01 PIPING INSTALLATION

A. All piping below concrete slabs, apron or roadways shall be incased in flowable backfill.

B. Install Flexible Expansion Joints with-in 1’-0” of building foundation wall below grade.

C. Install piping to conserve building space and not interfere with use of space.

D. Group piping whenever practical at common elevations.

E. Install a cleanout in the vertical riser (vent to drain transition) above the connection to each urinal to allow for individual cleaning of each fixture drain.

F. Install soil and waste drainage and vent piping at the following minimum slopes unless otherwise indicated. Engineer must obtain written approval from the DEN Mechanical Engineer for use of pipe slopes of less than 2 percent even though code allows a slope of 1 percent for some pipe sizes.

1. Building Sanitary Drain: 2 percent downward in direction of flow for all piping sizes downward in direction of flow (DN 100).
2. Horizontal Sanitary Drainage Piping: 2 percent downward in direction of flow.

3.02 TESTING

A. Perform all tests in the presence of the authorized City representative when required. Contractor shall provide inspector minimum 48-hour prior notice of test; also notify DEN Project Manager.

B. Pneumatic leak tests shall only be used on piping with restricted access, piping exposed to freezing conditions, or where water leakage would damage critical DEN operational equipment. Contractor shall submit a written request for test in accordance with the Submittals paragraph of this specification Section.

1. Compressed gas poses the risk of sudden release of stored energy. For that reason, pneumatic testing shall be used only within the following limitations.

a. For cast iron pipe or plastic pipe subject to brittle failure, finished plumbing test pressure shall not exceed 1-inch wg.

b. For cast iron pipe or plastic pipe subject to brittle failure, roughing in plumbing test pressure shall not exceed 5.0 psig.

c. For forced main piping, the system does not contain cast iron pipe or plastic pipe subject to brittle failure, soldered or solvent cement joints over NPS 2, and the test pressure does not exceed 150 psig.

2. Contractor shall measure the surface temperature of the pipe for the duration of testing. The pneumatic test will be deemed successful only when the test pressure can be held at a constant pipe surface temperature for a period of no less than 10 continuous minutes. Record of the pipe temperatures and pressures during the duration of the test shall be submitted to the DEN Project Manager following completion of the test.

C. Prepare written report of testing procedures and result and submit to DEN Project Manager.

Section 221319: Sanitary Waste Piping Specialties

PART 1 GENERAL

1.01 COORDINATION

A. Coordinate size and location of roof penetrations.

PART 2 PRODUCTS

2.01 FLOOR DRAINS

A. Verify that floor drain types are indicated on Drawings.

B. Cast-Iron Floor Drains:

1. Standard: ASME A112.6.3.
2. Lacquered finish is standard.
3. Use clamping collar on floors above grade.

C. FD-1: Lacquered cast iron two-piece body with double drainage flange, weep holes, reversible clamping collar, and round, adjustable nickel-bronze strainer.

D. Provide floor drain below in showers, washrooms, and general service areas;

E. FD-2: Same as FD-1 except with removable perforated sediment bucket and square strainer.

F. Provide floor drain below in equipment rooms and elsewhere for picking up indirect waste;

G. FD-3: Same as FD-1 except with polished bronze funnel or anti-splash rim type strainer.

H. Provide floor drain below in warehouse areas and other areas where subject to high point loads;

I. FD-4: Same as FD-1 except with extra heavy-duty strainers.

J. Provide floor drain below in vehicle areas;

K. FD-5: Same as FD-1 except with extra heavy-duty strainers with hinged grate and sediment bucket.

L. Provide trench drain below in parking areas and ramps, and where heavy traffic and large water volume occurs;

M. FD-6: Lacquered cast iron two-piece body with drainage flange, heavy duty grate 6 inches wide, 24 inches long, dome strainer, end plates with gaskets.

2.02 FLOOR SINKS

A. FS-1: Nickel bronze grate and cast iron body with dome strainer and cast iron seepage flange; acid-resisting porcelain enamel coated.

B. Provide floor sinks to accept indirect waste lines

C. FS-2: Square cast iron body with integral cast iron seepage pan, epoxy coated interior, nickel bronze grate and dome strainer, cast iron clamp collar, nickel bronze frame and half grate.

1. Provide FS-2 floor sink in food preparation areas.

2.03 AIR-ADMITTANCE VALVES

A. Fixture Air Admittance Valves, Stack Air Admittance Valves, and Wall Boxes are not allowed at DEN. Use Foot Vent or other venting approach.

PART 3 EXECUTION

3.01 INSTALLATION

A. For floor cleanouts for piping below floors, install cleanout deck plates with top flush with finished floor.

B. For cleanouts located in concealed piping, install cleanout wall access covers, of types indicated, with frame and cover flush with finished wall.

C. Extend cleanouts to finished floor or wall surface. Lubricate threaded cleanout plugs with mixture of graphite and linseed oil. Ensure clearance at cleanout for rodding of drainage system.

D. Extend cleanouts for piping below floors to the level that is being served. For tenant areas, cleanouts for sanitary, vent and grease piping shall be located inside the limits of the lease space. No in-line cleanouts shall occur below on in an adjacent space outside of the Tenant lease area.

Section 221323: Sanitary Waste Interceptors

PART 1 GENERAL

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train DEN Project Manager's maintenance personnel to adjust, operate, and maintain interceptors.

B. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 221329: Sanitary Sewerage Pumps

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include construction details, material descriptions, dimensions of individual components and profiles.

1. Include dimension drawings indicating components and connections to other equipment and piping.
2. Indicate pump type, capacity, impeller size, power requirements, and affected adjacent construction.
3. Submit certified pump curves showing pump performance characteristics with pump and system operating point plotted. Include NPSH curve when applicable.
4. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.

B. Wiring Diagrams: For power, signal, and control wiring.

C. Shop Drawings:

1. For each pump system and/or basin, include construction details, material descriptions, dimensions of components and profiles, rated capacities, furnished specialties, and accessories.
2. Include dimensions of tanks, tank lining methods, anchors, attachments, lifting points, tapings, and drains.
3. Detail equipment assemblies and weights, loads, required clearances, method of field assembly, components, and location and size of each field connection

1.02 QUALITY ASSURANCE

A. Perform Work in accordance with current Denver codes and standards.

B. Provide pumps with manufacturer's name, model number, and rating/capacity identified.

C. Product Options: Drawings indicate size, profiles, and dimensional requirements of packaged pumping stations and are based on the specific system indicated. Refer to Section 016000 "Product Requirements."

D. Ensure pumps operate at specified system fluid temperatures without vapor binding and cavitation, are non-overloading in parallel or individual operation, operate within 25 percent of midpoint of published maximum efficiency curve.

E. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency acceptable to authorities having jurisdiction, and marked for intended location and application.

F. UL Compliance: Comply with UL 778 for motor-operated water pumps.

G. HI Compliance: Comply with HI 1.1-1.5 for sewage and sump pumps.

H. NEMA Compliance: Comply with NEMA MG 1 for electric motors.

1.03 EXTRA MATERIALS

Extra stock materials may not be allowed on publicly funded projects. Coordinate extra stock submittal requirements with DEN Project Manager.

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Mechanical Seals: One (1) mechanical seal(s) for each type of pump.

1.04 WARRANTY

Coordinate warranty requirements with DEN Project Manager.

A. Provide minimum five (5) year warranty for submersible sump pumps, sump pumps and sewage ejectors.

PART 2 PRODUCTS

2.01 TERMINAL COMPLEX PUMPS

A. Sanitary Sewer

1. Submersible, Quick-Disconnect, Grinder Sewage Pumps:
2. Description: Factory-assembled and-tested, grinder sewage-pump unit with guide-rail supports.
3. Pump Type: Submersible, end-suction, single-stage, close-coupled, overhung-impeller, centrifugal sewage pump as defined in HI 1.1-1.2 and HI 1.3.

4. Pump Casing: Cast iron, with open inlet, and discharge fittings for connection to guide-rail supports.
5. Impeller: Bronze or stainless steel; statically and dynamically balanced, with stainless-steel cutter, grinder, or slicer assembly; capable of handling solids; and keyed and secured to shaft.
6. Pump and Motor Shaft: Stainless steel, with factory-sealed, grease-lubricated ball bearings.
7. Seal: Mechanical.
8. Motor: Hermetically sealed, capacitor-start type; with built-in overload protection; lifting eye or lug; and three-conductor, waterproof power cable of length required and with grounding plug and cable-sealing assembly for connection at pump.
   a. Motor Housing Fluid: Oil.

B. Industrial Sewer and Foundation Drain

1. Submersible, Quick-Disconnect, Single-Seal Sewage Pumps:
2. Description: Factory-assembled and-tested sewage-pump unit with guide-rail supports.
3. Pump Type: Submersible, end-suction, single-stage, close-coupled, overhung-impeller, centrifugal sewage pump as defined in HI 1.1-1.2 and HI 1.3.
4. Pump Casing: Cast iron, with open inlet, and discharge fittings for connection to guide-rail support.
5. Impeller: Statically and dynamically balanced, ASTM A 48/A 48M, Class No. 25 A cast iron, non-clog, open, or semi-open design for solids handling, and keyed and secured to shaft.
6. Pump and Motor Shaft: Stainless steel, with factory-sealed, grease-lubricated ball bearings.
7. Seal: Mechanical.
8. Motor: Hermetically sealed, capacitor-start type; with built-in overload protection; lifting eye or lug; and three-conductor, waterproof power cable of length required and with grounding plug and cable-sealing assembly for connection at pump.
   a. Motor Housing Fluid: Oil.

2.02 CONTROLS

A. Enclosure: NEMA 250, Type 4X wall-mounted.

B. Switch Type: Mercury free float type, in NEMA 250, Type 6 enclosures with mounting rod and electric cables.

C. Automatic Alternator: Start pumps on successive cycles and start multiple pumps if one cannot handle load.

D. High-Water Alarm: Rod-mounted, NEMA 250, Type 6 enclosure with mercury free float switch matching control and electric bell; 120-V ac, with transformer and contacts for remote alarm bell.

E. Control-Interface Features:

1. Remote Alarm Contacts: For remote alarm interface.
2. Building Automation System Interface: Auxiliary contacts in pump controls for interface to building automation system and capable of providing the following:
   a. Ability to interface with BACNet Control Systems.
   b. On-off status of pump.
   c. Alarm status.

2.03 SEWAGE PUMP PITS

A. Description: Concrete pit with sump, pipe connections, curb frame, and separate cover.

> Due to heaving soils at DEN, coordinate concrete pump pits with structural engineer. Sumps must be properly designed and supported to prevent damage from soil heaving and other local conditions.

PART 3 EXECUTION

3.01 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

1. Complete installation and startup checks according to manufacturer's written instructions.
2. Verify bearing lubrication.
3. Disconnect couplings and check motors for proper direction of rotation.
4. Verify that each pump is free to rotate by hand. If pump is bound or drags, do not operate until cause of trouble is determined and corrected.
5. Verify that pump controls are correct for required application.

B. Occupancy Adjustments: When requested by DEN Project Manager within twelve (12) months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions.

1. Provide up to two (2) visits to Project outside normal occupancy hours for this purpose.

3.02 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain controls and pumps.

B. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days' advance notice.

Section 221343: Facility Packaged Sewage Pumping Stations

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories. Include data substantiating that materials comply with requirements.

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain packaged sewage pumping stations. Refer to Section 017900 “Demonstration and Training.”

B. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 221413: Facility Storm Drainage Piping

PART 1 GENERAL

PART 2 PRODUCTS

2.01 GENERAL

A. No cast Iron pipe or fittings allowed below grade or slabs.

PART 3 EXECUTION

3.01 PIPING INSTALLATION

A. General: Install piping and clean-outs in accordance with the Denver Wastewater Management standards, specifications, and as per the standard detail drawings.

B. All piping below concrete slabs, apron or roadways shall be incased in flowable backfill.

C. Interior Inspection: Inspect piping to determine whether line displacement or other damage has occurred.

1. Make inspections after lines have been installed and approximately 24” of backfill is in place, and again at completion of Project.

3.02 IDENTIFICATION OF UNDERGROUND PIPING

A. General: During back filling/top soiling of storm sewer system, install continuous underground type plastic line marker, located directly over buried line at 18" below finished grade.

3.03 FIELD QUALITY CONTROL

A. During installation, notify authorities having jurisdiction and DEN Project Manager at least 48 hours before inspection must be made. Perform tests specified below in presence of authorities having jurisdiction.

1. Perform testing of completed piping in accordance with Section 9.00 of the Denver Wastewater Management Division Technical Specifications. Inform DEN Project Manager 48 hours prior to testing and backfilling.
2. Testing shall be witnessed by DEN Mechanical Inspector and DEN Project Manager or Designated Representative.
3. Roughing-in Inspection: Arrange for inspection of piping before concealing or closing-in after roughing-in.
4. Final Inspection: Arrange for final inspection by authorities having jurisdiction to observe tests specified below and to ensure compliance with requirements.

B. The following tests shall be performed on the piping:

TEST	SYSTEM TYPE
Exfiltration Test	All systems
Infiltration Test	Only in case of excessive ground water
Deflection Test	Only plastic piping

C. No piping or joint shall be left untested. All leaks shall be repaired and the piping system shall be re-tested until satisfactory results are obtained.

D. Repair piping systems which fail required piping test, by disassembly and reinstallation, using new materials to extent required to overcome leakage. Do not use chemicals, stop-leak compounds, mastics, or other temporary repair methods.

3.04 INSPECTION

A. The storm piping system shall be inspected by the Contractor's Quality Control Inspector. A record of the inspection including any defects deviations from the contract shall be submitted to the DEN Project Manager.

Section 221423: Storm Drainage Piping Specialties

PART 1 GENERAL

PART 2 PRODUCTS

2.01 PLASTIC ROOF DRAINS

A. Plastic roof drains are prohibited.

PART 3 EXECUTION

Section 221429: Sump Pumps

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include construction details, material descriptions, dimensions of individual components and profiles.

1. Include dimension drawings indicating components and connections to other equipment and piping.
2. Indicate pump type, capacity, impeller size, power requirements, and affected adjacent construction.
3. Submit certified pump curves showing pump performance characteristics with pump and system operating point plotted. Include NPSH curve when applicable.
4. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.

B. Wiring Diagrams: For power, signal, and control wiring.

C. Shop Drawings:

1. For each pump system and/or basin, include construction details, material descriptions, dimensions of components and profiles, rated capacities, furnished specialties, and accessories.
2. Include dimensions of tanks, tank lining methods, anchors, attachments, lifting points, tapings, and drains.
3. Detail equipment assemblies and weights, loads, required clearances, method of field assembly, components, and location and size of each field connection

1.02 QUALITY ASSURANCE

A. Source Limitations: Obtain pumps through one source from a single manufacturer.

B. Provide pumps with manufacturer's name, model number, and rating/capacity identified.

C. UL Compliance: Comply with UL 778 for motor-operated water pumps.

D. HI Compliance: Comply with HI 1.1-1.5 for sewage and sump pumps.

E. NEMA Compliance: Comply with NEMA MG 1 for electric motors.

F. Ensure products and installation of specified products are in conformance with recommendations and requirements of the following organizations:

1. UL Compliance: Comply with UL 778 for motor-operated water pumps.
2. National Electrical Manufacturers' Association (NEMA).
3. DEN's insurance underwriter.

1.03 EXTRA MATERIALS

Extra stock materials may not be allowed on publicly funded projects. Coordinate extra stock submittal requirements with DEN Project Manager.

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Mechanical Seals: One (1) mechanical seal(s) for each type of pump.

PART 2 PRODUCTS

2.01 GENERAL

A. Construction to permit complete servicing without breaking piping or motor connections.

B. Pump connections to be flanged.

2.02 MOTOR

A. Hermetically sealed, capacitor-start type; with built-in overload protection; lifting eye or lug; and three-conductor, waterproof power cable of length required and with grounding plug and cable-sealing assembly for connection at pump.

1. Motor Housing Fluid: Oil.

2.03 CONTROLS

A. Enclosure: NEMA 250, Type 4X wall-mounted.

B. Switch Type: Mercury free float type, in NEMA 250, Type 6 enclosures with mounting rod and electric cables.

C. Automatic Alternator: Start pumps on successive cycles and start multiple pumps if one cannot handle load.

D. High-Water Alarm: Rod-mounted, NEMA 250, Type 6 enclosure with mercury free float switch matching control and electric bell; 120-V ac, with transformer and contacts for remote alarm bell.

E. Control-Interface Features:

1. Remote Alarm Contacts: For remote alarm interface.
2. Building Automation System Interface: Auxiliary contacts in pump controls for interface to building automation system and capable of providing the following:
   a. Ability to interface with BACNet Control Systems.
   b. On-off status of pump.
   c. Alarm status.

PART 3 EXECUTION

3.01 INSTALLATION

A. Ensure pumps operate at specified system fluid temperatures without vapor binding and cavitation, are non-overloading in parallel or individual operation, and operate within 25 percent of midpoint of published maximum efficiency curve.

3.02 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain equipment.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 221513: General-Service Compressed-Air Piping

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Product Data: For the following:

1. Pipes, fittings, and valves.
2. Dielectric fittings.
3. Flexible pipe connectors.
4. Safety valves.

5. Pressure regulators. Include rated capacities and operating characteristics.
6. Automatic drain valves.
7. Filters. Include rated capacities and operating characteristics.
8. Lubricators. Include rated capacities and operating characteristics.
9. Quick couplings.
10. Hose assemblies.

1.02 PROJECT CONDITIONS

A. Interruption of Existing Compressed-Air Service: Do not interrupt compressed-air service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary compressed-air service according to requirements indicated:

1. Notify DEN Project Manager no fewer than seven (7) days in advance of proposed interruption of compressed-air service.
2. Do not proceed with interruption of compressed-air service without DEN Project Manager's written permission.

PART 2 PRODUCTS

2.01 PIPES, TUBES, AND FITTINGS

A. Plastic pipe and fittings are not allowed.

PART 3 EXECUTION

3.01 PIPING APPLICATIONS

A. Copper piping shall have brazed joints.

Section 221519: General-Service Packaged Air Compressors and Receivers

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.

Delegated design for compressed-air equipment mounting is not allowed at DEN. Remove all references to delegated design for compressed-air equipment mounting from the Specifications.

1.02 MAINTENANCE MATERIAL SUBMITTALS

Extra stock materials may not be allowed on publicly funded projects. Coordinate extra stock submittal requirements with DEN Project Manager.

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Air-Compressor, Inlet-Air-Filter Elements: Equal to 10 percent of amount installed, but no fewer than one units.
2. Belts: One for each belt-driven compressor.

1.03 PROJECT CONDITIONS

A. Interruption of Existing Compressed-Air Service: Do not interrupt compressed-air service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary compressed-air service according to requirements indicated:

1. Notify DEN Project Manager no fewer than seven (7) days in advance of proposed interruption of compressed-air service.
2. Do not proceed with interruption of compressed-air service without DEN Project Manager's written permission.

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain air compressors, aftercoolers, and air dryers.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 223300: Electric, Domestic-Water Heaters

PART 1 GENERAL

1.01 WARRANTY

Coordinate warranty requirements with DEN Project Manager.

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of electric, domestic-water heaters that fail in materials or workmanship within specified warranty period.

1. Failures include, but are not limited to, the following:
   a. Structural failures including storage tank and supports.
   b. Faulty operation of controls.
   c. Deterioration of metals, metal finishes, and other materials beyond normal use.

PART 2 PRODUCTS

2.01 GENERAL

A. All water heaters shall have an expansion tank, regardless of the water heater size.

B. For increased efficiency, heat-pump water heaters shall be considered.

PART 3 EXECUTION

3.01 DOMESTIC-WATER HEATER INSTALLATION

A. Engineer shall calculate all precharges for domestic-water compression tanks and indicate with-in the design documents. Engineer shall not rely on manufacturer's standard precharge.

3.02 CONNECTIONS

A. Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified in piping systems.

B. Where installing piping adjacent to electric, domestic-water heaters, allow space for service and maintenance of water heaters. Arrange piping for easy removal of domestic-water heaters.

3.03 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain commercial and tankless, electric, domestic-water heaters.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 223400: Fuel-Fired, Domestic-Water Heaters

PART 1 GENERAL

1.01 WARRANTY

Coordinate warranty requirements with DEN Project Manager.

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of fuel-fired, domestic-water heaters that fail in materials or workmanship within specified warranty period.

1. Failures include, but are not limited to, the following:

a. Structural failures including storage tank and supports.

b. Faulty operation of controls.

c. Deterioration of metals, metal finishes, and other materials beyond normal use.

PART 2 PRODUCTS

2.01 GENERAL

A. Provide electric water heaters, when water heaters are required. Gas-fired water heaters may be used with written acceptance of the DEN Mechanical Engineer and verification there is adequate volume in space for combustion air and an accessible route for flue.

B. All water heaters shall have an expansion tank, regardless of the water heater size.

C. For increased efficiency, heat-pump water heaters shall be considered

PART 3 EXECUTION

3.01 CONNECTIONS

A. Coordinate piping installations and specialty arrangements with schematics on Drawings and with requirements specified in piping systems.

B. Where installing piping adjacent to domestic-water heaters, allow space for service and maintenance of water heaters. Arrange piping for easy removal of domestic-water heaters.

3.02 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain commercial, gas-fired, storage, and gas-fired, tankless domestic-water heaters.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 223500: Domestic-Water Heat Exchangers

PART 1 GENERAL

1.01 WARRANTY

A. Coordinate warranty requirements with DEN Project Manager.

B. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of fuel-fired, domestic-water heaters that fail in materials or workmanship within specified warranty period.

1. Failures include, but are not limited to, the following:
   a. Structural failures including storage tank and supports.
   b. Faulty operation of controls.
   c. Deterioration of metals, metal finishes, and other materials beyond normal use.

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain shell-and-tube and circulating domestic-water heat exchangers.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 224213.13: Commercial Water Closets

PART 1 GENERAL

PART 2 PRODUCTS

2.01 WALL-MOUNTED WATER CLOSETS

A. Water closets shall be a wall hung, blow out type.

B. Tank-type/cistern-type water closets shall not be used in the terminal complex.

2.02 FLUSHOMETER VALVES

A. Automatic valves shall be provided for water closets in public areas.

B. Lever handle Flushometer Valves not to be used in public spaces. Only allowed in non-public spaces.

C. Consumption: 1.0 GPF

D. Hard-Wired, Solenoid-Actuator, Piston Flushometer Valves:

1. Hidden, infrared fushometer valves to be used at all public water closets.
2. Battery powered devices shall not be used

E. Isolation valves shall be provided on all fixtures.

PART 3 EXECUTION

3.01 INSTALLATION

A. All water closets shall have a double cleanout on the sanitary or vent riser prior to connection to the main piping to allow for cleaning of piping to the fixture and from the fixture branch to the main.

B. Double cleanout assembly shall be completely detailed on the contract documents.

Section 224213.16: Commercial Urinals

PART 1 GENERAL

PART 2 PRODUCTS

2.01 URINALS

A. Stall urinals are not to be used at DEN.

B. Waterless urinals shall not be allowed for use at any DEN facility.

2.02 WALL-HUNG URINALS

A. Urinals shall be a wall hung, blow out type.

2.03 FLUSHOMETER VALVES

A. Automatic valves shall be provided for urinals in public areas.

B. Lever handle Flushometer Valves not to be used in public spaces. Only allowed in non-public spaces.

C. Consumption: 0.125 GPF

D. Hard-Wired, Solenoid-Actuator, Piston Flushometer Valves:

1. Hidden, infrared fushometer valves to be used at all public urinals.
2. Battery powered devices shall not be used

E. Isolation valves shall be provided on all fixtures.

PART 3 EXECUTION

3.01 INSTALLATION

A. To prevent urine salt buildup, urinals shall connect directly downstream of water closet sanitary sewer main for allowance of future low flow fixtures. Urinals shall not be headered together and then connected to the sanitary mains. All urinals shall have a double cleanout on the sanitary or vent riser prior to connection to the main piping to allow for cleaning of piping to the fixture and from the fixture branch to the main.

B. Double cleanout assembly shall be completely detailed on the contract documents.

Section 224216.13: Commercial Lavatories

PART 1 GENERAL

1.01 GENERAL

All lavatories (including physically disabled) can be wall hung or counter mounted. Wheelchair access must be provided for handicap fixtures. A minimum 29" clear knee space is required with maximum 34" rim height or as defined by the latest version of the ADA.

Indicate on Drawing those lavatories that are required to be accessible.

PART 2 PRODUCTS

2.01 FAUCETS

A. All lavatory faucets in public and private toilet rooms shall be provided with flow restricting devices on all outlets.

B. Provide single tempered water faucet at lavatories with 102°F supply temperature available within 30 seconds of activation and for a period of not less than 20 seconds.

C. Private toilet room lavatory shall be specified to flow no more than 0.35 GPM.

D. Automatic valves shall be provided for lavatories in public areas. Valves shall be concealed and provided with infrared sensors for valve actuation. Battery powered devices shall not be used.

E. Automatic lavatory faucets shall be specified to flow no more than 0.5 GPM and are to use no more than 0.25 gallons of water per metering cycle.

F. Isolation valves shall be provided on all faucets.

PART 3 EXECUTION

Section 224216.16: Commercial Sinks

PART 1 GENERAL

1.01 GENERAL

Indicate on Drawing those sinks that are required to be accessible.

PART 2 PRODUCTS

2.01 SERVICE BASINS

A. Drains from service and slop sinks shall be minimum of 3-inch diameter.

2.02 SINK FAUCETS

A. Kitchen/breakroom type sinks shall be specified to flow no more than 1.5 GPM.

2.03 SUPPLY FITTINGS

A. Stop valves shall be provided on all faucets.

B. Supply Stops: Chrome-plated brass, one-quarter-turn, ball-type or compression valve with inlet connection matching supply piping.

PART 3 EXECUTION

Section 224223: Commercial Showers, Receptors, and Basins

PART 1 GENERAL

PART 2 PRODUCTS

2.01 SHOWER FAUCETS

A. Isolation valves shall be provided on all faucets.

B. Shower faucets

C. shall be specified to flow no more than 1.75 GPM.

PART 3 EXECUTION

Section 224233: Wash Fountains

PART 1 GENERAL

PART 2 PRODUCTS

2.01 GENERAL

A. Provide single tempered water faucet at lavatories with 102°F supply temperature available within 30 seconds of activation and for a period of not less than 20 seconds.

B. Automatic valves shall be concealed and provided with infrared sensors for valve actuation. Battery powered devices shall not be used.

C. Liquid-Soap Dispensers: Hardwired, sensor actuated for each user station. Battery powered devices shall not be used.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install water-supply piping with shutoff valve on each supply to each wash fountain to be connected to domestic-water distribution piping. Use ball, gate, or globe valve. Install valves in locations where they can be easily reached for operation.

Section 224713: Drinking Fountains

PART 1 GENERAL

PART 2 PRODUCTS

2.01 BOTTLE FILLING STATION AND ADA REFRIGERATED DRINKING FOUNTAIN

A. Provide drinking fountain to provide a chilling capacity of 8.0 GPH of 50°F drinking water, per ASHRAE 18 testing. Hands Free operation, laminar flow, visual filter monitor and bubbler. Electronic Bottle Filler Sensor with Hands Free bubbler activation. Product shall be wall mount type for Indoor applications. Unit shall be ADA, ASME and NSF compliant, certified to UL 399. Unit can be part of a bi-level unit.

2.02 GENERAL

A. Isolation valves shall be provided on all faucets.

B. Waters Fountains should be selected in pairs; the Handicap fountain should also have a water-bottle filler.

C. Vitreous China drinking fountains should not be used in public areas.

PART 3 EXECUTION

Section 224716: Pressure Water Coolers

PART 1 GENERAL

PART 2 PRODUCTS

2.01 GENERAL

A. Isolation valves shall be provided on all fixtures.

B. Pressure Water Coolers should be selected in pairs; the Handicap fountain should also have a water-bottle filler.

C. Semi-recessed pressure water coolers should not be used at DEN.

PART 3 EXECUTION

12.3 DEN Technical Requirements - Division 23: Heating, Ventilating, and Air-Conditioning (HVAC)

Except where directed by designer notes, add the following requirements to all project specification sections. Where there are similar or matching specification section names, include all content below in addition to the content in the generic specifications. The content below may be omitted where related equipment, mechanical systems, and furnishments are not in the project scope.

Section 230400: Basic HVAC Requirements

Engineer to include all aspects of this specification section though out the project specifications. This section includes aspects that are common to multiple sections.

PART 1 GENERAL

1.01 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and DEN specification Division 01 Specification Sections, apply to this Division.

1.02 SUMMARY

A. Provide, unless specified otherwise, all labor, materials, and equipment necessary for completely finished and operational HVAC systems described and specified under other Sections of this Division 23.

B. Provide all minor incidental items such as offsets, fittings, and accessories required as part of the work even though not specified or indicated.

1.03 ALTERNATES

A. Alternates: Refer to DEN specification Division 01 Section 012300 “Alternates” for description of Work in this Division affected by Alternates.

1.04 REFERENCES

A. Schedule of Referenced Organizations: Reference DEN specification Section 014210 “Referenced Material” for a list of the acronyms of organizations referenced in these Specifications.

1.05 DEFINITIONS

A. Conform to DEN specification Division 01: These Specifications are of abbreviated, simplified, or streamlined type and include incomplete sentences. Singular words will be interpreted as plural and plural words will be interpreted as singular where applicable and where full context of the Contract Documents so indicates.

B. Terminal Complex refers to the Main Terminal (Great Hall), Concourses, Central Utility Plant (CUP), Hotel, and the Transportation Center.

1.06 QUALITY CONTROL

A. Conform to DEN specification Division 01. Materials and apparatus required for the Work to be new and of first-class quality; to be furnished, delivered, erected, connected and finished in every detail; and to be so selected and arranged so as to fit properly into the building spaces.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

C. NFPA Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handling units and components.

D. ARI Certification: Air-handling units and their components shall be factory tested according to ARI 430, “Central-Station Air-Handling Units,” and shall be listed and labeled by ARI.

E. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5- “Systems and Equipment” and Section 7- “Construction and Startup.”

F. Comply with ARI 410 for components, construction, and rating.

1. Certificates: Certify that coil capacities, pressure drops, and selection procedures meet or exceed specified requirements.

G. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc., or other testing agency acceptable to the authority having jurisdiction, as suitable for the purpose specified and indicated.

H. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6- “Heating, Ventilating, and Air-Conditioning.”

I. Manufacturer: Company specializing in manufacturing the Products specified in this Section with minimum three (3) years documented experience, who issues complete catalog data on total product. Products are to be of the latest design to avoid becoming untimely obsolete.

J. Certificates confirming that all insulation, jacket, adhesives, mastics, sealers, etc., utilized in the fabrication of these systems shall meet NFPA for fire resistant ratings of a maximum of 25 flame spread and 50 smoke developed ratings, or more stringent requirements as required, and shall be approved by the insulation manufacturer for guaranteed performances when incorporated into their insulation system, unless a specific product is specified for a specific application, and is stated as an exception to this requirement.

1.07 REGULATORY REQUIREMENTS

A. Comply with latest editions of the Denver Amendments to the International Codes.

B. Where hourly fire ratings are indicated or required, provide components and assemblies meeting requirements of the American Insurance Association, Factory Mutual Insurance Association and listed by Underwriters Laboratories, Inc.

C. Ensure products and installation of specified products are in conformance with recommendations and requirements of DEN's insurance underwriter.

1.08 PRODUCT OPTIONS AND SUBSTITUTIONS

A. Substitutions: Refer to DEN specification Division 01, General Requirements.

B. When alternate or substitute materials and equipment are used, Contractor shall be responsible for space requirements, configurations, performance, changes in bases, supports, structural members and openings in structure, electrical changes and other apparatus and trades that may be affected by their use.

C. When providing a product and/or service under the qualification of “acceptable equal,” Contractor shall be entirely responsible for additional costs incurred due to modifications to the civil, architectural, structural, mechanical, and electrical design that may be required to accommodate the “acceptable equal.”

D. Substitute materials and equipment are only allowed to be provided from the Manufacturers listed as approved.

1.09 SHOP DRAWINGS AND PRODUCT DATA

A. General: Comply with the General Conditions of the Contract and with DEN specification Division 01- General Requirements.

B. Shop drawings detailing fabrication and installation for metal supports and anchorage for HVAC materials and equipment. In general, wood supports are not allowed for HVAC equipment. Coordinate any requirement for wood supports with the DEN project manager.

C. Prepare shop drawings according to DEN specification Division 01 Section to a 1/4 inch equals 1 foot scale or larger for approval from DEN Mechanical Engineer prior to start of any fabrication. Detail major elements, components, and systems of HVAC equipment and materials in relationship with other systems, installations, and building components. Show space requirements for installation and access. Show where sequence and coordination of installations are important to the efficient flow of the Work. Include the following:

1. Clearances for servicing and maintaining equipment, including space for equipment disassembly required for periodic maintenance.
2. Equipment and piping steel support details.
3. For fabricated items, indicate dimensions, weights, and placement of openings and holes.
4. For Division 23 systems: Include plans, elevations, sections, details, and frames and covers.
5. Show piping materials, size, locations, and elevations.

6. Detail fabrication of pipe anchors, alignment guides, expansion joints and loops, and their attachment to the building structure.
7. Indicate location of anchors, alignment guides, and expansion joints and loops.
8. Include details of structures, and connections. Show interface and spatial relationship between ductwork, piping and proximate structures.
9. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.
10. Detail attachment and covering of heat tracing inside insulation.
11. Sign, seal, and prepare the following by or under the supervision of a qualified professional engineer:
    a. Detail equipment assemblies and indicate dimensions, weights, loads, method of field assembly, components, and location and size of each field connection.
    b. Required clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.
    c. Show proposed physical layout of equipment relative to the space in which it is to be installed.
    d. Coordination of equipment, piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
    e. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.
    f. Design Calculations: Calculate requirements for selecting vibration isolators, restraints and for designing vibration isolation bases.
    g. Detail fabrication and assembly of gas-fired heating and ventilating units, as well as procedures and diagrams.
    h. Wiring Diagrams: For power, signal, and control wiring.
    i. Mounting Details: For securing and flashing roof curb to roof structure. Indicate coordinating requirements with roof membrane system.

D. Electronic/CAD floorplan backgrounds are available upon request.

E. All documents shall be submitted in electronic format. Each submittal shall be in a single security free PDF document. PDF documents shall be compatible with Adobe Acrobat 10.0 or newer. All as-built documents shall be submitted in Revit in accordance with DEN specification Division 1 requirements.

F. Submittals shall constitute a representation to Owner and Engineer that Contractor has both determined and verified all quantities, dimensions, field construction criteria, materials, catalog numbers and similar data or he assumes full responsibility for doing so, and that he has coordinated each Submittal with the requirements of the Work and the Contract Documents. Contractor certifies that the Material and Equipment shown and marked on the Submittals are in compliance with the Contract Documents and can be installed, operated, and maintained in the allocated space. Submittal is to include, but not limited to, the following:

1. Piping fabrication drawings.
    a. Include in-plan view of all systems piping 2-1/2 inches and larger. Provide isometrics for piping systems or tubing 2 inches in diameter and smaller.
    b. Show the actual Equipment furnished, Equipment location by dimension, and connections.
    c. Include temporary piping and connections to the permanent piping necessary for flushing and cleaning.
    d. Dimension pipelines in plan view and locate in elevation. Indicate support locations.

e. Submit before fabrication is begun.

1.10 CONTRACT RECORD DOCUMENTS

Verify requirements for as-built plans with DEN Project Manager.

A. General: Comply with the General Conditions of the Contract and with DEN specification Division 01- General Requirements.

B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in DEN specification Section 013300 “Submittal Procedures”. All as-built documents shall be submitted in Revit in accordance with DEN specification Division 1 requirements. Plans to include but not limited to:

1. Actual locations of duct and pipe including elevations for Division 23 systems. Include dimensions off of grid-lines.
2. Actual elevation of any duct or pipe passing through a structural element (foundation walls, grade or steel beams, shear walls, etc.).
3. Actual locations of flexible pipe connectors, expansion joints, anchors, and guides.
4. Actual locations of valves.
5. Actual locations of heat trace components.
6. Actual locations of hangers including attachment points.
7. Actual locations of equipment, condensate drains, cleanouts, backflow preventers.

1.11 OPERATING AND MAINTENANCE DATA

A. Division 23 Contractor shall submit electronic copy containing a single PDF file of the entire maintenance manual to the DEN Project Manager, General Contractor for their approval.

B. The manual shall have:

1. Alphabetical list of all system components including the name, address, and 24-hour phone number of the company responsible for servicing each item during the first year's operation.
2. Operating instructions for complete system, including emergency procedures for fire or failure of major equipment and procedures for normal starting/operating/shutdown and long-term shutdown.
3. Maintenance instructions, including valves, valve tag and other identified equipment lists, proper lubricants and lubricating instructions for each piece of equipment and necessary cleaning/replacing/adjusting schedules. Include installation instructions, spare parts lists and exploded assembly views.
4. Manufacturer's data on each piece of equipment, including:
   a. Installation instructions.
   b. Drawings and specifications (approved shop drawings).
   c. Parts lists.
   d. Complete wiring and temperature control diagrams (approved shop drawings).
5. Each piece identified on any schedule shall be bookmarked in the electronic file by its scheduled tag ID (IE: TML_04_11A_EUH_01).

C. In addition to the maintenance manual, and keyed to it, the equipment shall be identified and tagged as specified.

1. Identify all starters, disconnect switches, and manually operated controls, except integral equipment switches with permanently applied, legible markers corresponding to operating instructions in the “Maintenance Manual”.
2. Tag all manual operating valves with 1-1/2" diameter brass tags attached with chains. Tags are to be sequence numbered with legible metal stamps.

3. Provide a typed tag list or schedule mounted under glass in the room designated by DEN Project Manager stating number, location, and function of each tagged item. Insert a copy of tag list in each “Maintenance Manual”.

D. Division 23 Contractor shall be responsible for scheduling instructional meetings for maintenance personnel on the proper operation and maintenance of all mechanical systems, using the maintenance manual as a guide. These meetings must be scheduled through the DEN Project Manager, and General Contractor far enough in advance so that all personnel can be notified.

E. Division 23 Contractor shall provide proof of performance certification of all Mechanical Equipment and Systems to demonstrate that all Mechanical Equipment and Systems are operating to the intent of the design.

1.12 FINAL OBSERVATION

A. Comply with the requirements of DEN specification Division 01 and the following:

1. Prior to the request for final observation, all Work under the contract shall be complete; all systems shall be in proper working order and placed in operation for a minimum duration of 48 hours.
2. All HVAC systems shall be properly balanced with quantities shown on the Drawings, and all water circuits shall be adjusted to provide the proper flows.
3. All equipment shall be cleaned. All debris and construction materials shall be removed from the DEN property to a DEN approved landfill off-airport.
4. The temperature control system shall be complete and in proper working order. All instruments shall be properly and accurately field calibrated.
5. At the request of the DEN Project Manager, a representative of the Contractor who is thoroughly familiar with the Project and operation of the various systems shall be present during the final observation to demonstrate proper operation of the equipment and controls. If requested by the DEN Project Manager, the Contractor shall have representatives from the Contractor's subcontractors present to assist during final observation.

1.13 PROJECT CONDITIONS

A. Accessibility:

1. Division 23 Contractor shall be responsible for the sufficiency of the size of shafts and chases and the adequate clearance in double partitions and hung ceilings for proper installation of his work. He shall cooperate with Contractors of other Divisions of the Work whose work is in the same space and shall advise the General Contractor of his requirements. Such spaces and clearances shall, however, be kept to the minimum size required.
2. Division 23 Contractor shall locate all equipment, which must be serviced, operated, or maintained in fully accessible positions. Such equipment shall include (but not be limited to) valves, shock absorbers, motors, controllers, switchgear, and drain points. If required for better accessibility, furnish access doors for this purpose. Minor deviations from Drawings may be allowed to provide for better accessibility. Any changes shall be approved by the DEN Project Manager prior to making the change.
3. Division 23 Contractor shall provide the General Contractor with the exact locations of access doors for each concealed valve, shock absorber control, damper, or other device requiring service. Locations of these doors shall be submitted in sufficient time to be installed in the normal course of work.
4. Provide carpentry, masonry, concrete and metal work required for work of this Division where not specifically called for under other Sections.

B. Freeze Protection:

1. Do not run HVAC systems piping in outside walls, or locations where freezing may occur. Piping next to outside walls shall be in furred spaces with insulation between the piping and the outside wall. Insulation of piping shall not be considered freeze protection.

C. Interruption of Service: Do not interrupt services to facilities occupied by DEN, DEN Tenant or others unless permitted under the following conditions and then only after arranging to provide temporary services according to requirements indicated:

1. Notify DEN Project Manager no fewer than seven (7) days in advance of proposed interruption of water service.
2. Do not interrupt services without DEN Project Manager's written permission.
3. Comply with DEN specification Division 01.

D. Altitude above Mean Sea Level: 5,500 feet.

1.14 COORDINATION

A. General: Coordinate and order the progress of Division 23 Work to conform to the progress of the Work of the other trades. Complete the entire installation as soon as the condition of the building will permit.

B. Coordinate Work with Division 21 Fire Suppression, Division 22 Plumbing, Division 26 Electrical, and Division 33 Utilities and other Divisions as required to perform the Work.

C. Cutting and Patching: Reference Section DEN specification 017330 “Cutting and Patching”.

D. Drawings and Specifications: The Mechanical Drawings indicate the general design and arrangement of lines, equipment, systems, etc. Information shown is diagrammatic in character and does not necessarily indicate every required offset, fitting, etc. Do not scale the Drawings for dimensions. Take dimensions, measurements, locations, levels, etc., from the Architectural and Engineering Drawings and equipment to be furnished.

E. Discrepancies: Examine Drawings and Specifications for other parts of the Work, and if any discrepancies occur between the plans for the Work of this Division and the plans for the work of others, report such discrepancies to the DEN Project Manager and obtain written instructions for any changes necessary.

F. Order of Precedence: The precedence of construction documents are as Specified in the General Conditions.

G. Coordination Drawings: Floor plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

H. Mechanical-room layout and relationships between components and adjacent structural and mechanical elements.

a. Support location, type, and weight.
b. Field measurements.
c. Size and location of unit-mounted rails and anchor points and methods for anchoring units to roof curb.
d. Required roof penetrations for ducts, pipes, and electrical raceways, including size and location of each penetration.

I. For any work done in the Central Utility Plant (CUP) provide schedule specific to work to be done above, or around any existing equipment to DEN Project Manager and CUP operators at least 2 weeks prior to start of work.

1.15 START-UP PROCEDURES

A. Before start-up, each piece of equipment comprising a part of the system shall be checked for proper lubrication, drive rotation, belt tension, proper control sequence, and any other condition, which may cause damage to equipment or endanger personnel.

B. Ensure that all control systems are fully operational in automatic mode.

C. If systems are not to continue in use following the start-up procedures, steps should be taken to ensure against accidental operation or operation by unauthorized personnel.

D. Factory personnel shall be notified as appropriate to start systems requiring their services.

E. Notify the DEN Project Manager in writing a minimum of 72 hours prior to start-up of all major mechanical equipment and systems if no shutdown request is required.

F. Should there be any equipment found which had not been properly started up, it will be the responsibility of this Contractor to arrange for the appropriate personnel to start up the equipment at the Contractor's expense and at a time as scheduled by the DEN Project Manager.

1.16 SCHEDULE OF TESTING

A. Do not operate units for any purpose, temporary or permanent, until ductwork is clean, filters are in place, bearings lubricated, and fan has been test run under observation.

B. Do not operate units for temporary heating or cooling prior to substantial completion without approval by DEN Project Manager.

C. Provide testing in accordance with the General Conditions of the Contract.

D. A schedule of testing shall be drawn up by the Division 23 Contractor in such a manner that it will show areas tested, test pressure, length of test, date, time and signature of testing personnel.

E. Notify the DEN Project Manager, DEN Mechanical Inspector and DEN Mechanical Engineer in writing a minimum of 72 hours prior to testing of any mechanical equipment and systems if no shutdown request is required.

F. All testing must be performed in the presence DEN Project Manager and or designated representative; the DEN Project Manager's signature for verification of the test must appear on the schedule.

G. All testing must be performed in accord with the procedures set forth in Division 23 and other Sections of the Specifications where referenced. At completion of testing, the schedule shall then be submitted in triplicate to the DEN Project Manager.

1.17 CLEANING AND FINISHING

A. Provide cleaning in accordance with the General Requirements of the Contract.

B. Cleaning shall include but not be limited to removing grease, dirt, dust, stains, labels, fingerprints, and other foreign materials from sight-exposed piping, ductwork, equipment, fixtures and other such items installed under Division 23 of the work. If finishes have been damaged, refinish to original condition and leave everything in proper working order and of intended appearance.

C. Clean HVAC Systems in accordance with applicable Division 23 Sections.

1.18 EXTRA MATERIALS

Extra stock materials may not be allowed on publicly funded projects. Coordinate extra stock submittal requirements with DEN Project Manager.

1.19 WARRANTIES

Coordinate warranty requirements with DEN Project Manager.

A. Conform to DEN specification Division 01: Provide a written warranty covering the entire Division 23 Work to be free from defective materials, equipment, and workmanship for a minimum period of two (2) years after date of acceptance. During this period, provide labor and materials as required to repair or replace defects.

B. Provide certificates for such items of equipment, which have or are specified to have warranties in excess of two (2) years.

1.20 CONSTRUCTION WASTE MANAGEMENT

Coordinate requirements with DEN Project Manager.

A. Construction waste shall be managed in accordance with provisions of DEN specification Section 017419 “Construction Waste Management and Disposal”. Documentation shall be submitted to satisfy the requirements of that Section.

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 FLUSHING AND CLEANING FOR CLOSED HYDRONIC SYSTEMS – METALLIC PIPING SYSTEMS

Engineer to include methods for testing, flushign, and cleaning of metallic closed piping systems. Include locations for the installation of slip blind and blind flanges or other appurtenances for isolating new piping and equipment from the old. On the contract drawings include methods for testing, flushing, and cleaning in the hydronic flow diagram including any temporary valves, spool pieces, and a list of equipment that is not to be installed such that flushing can occur. Use multiple flow diagrams as necessary to convey this requirement; do not describe this requirement in the specifications without the use of flow diagrams. Do not use existing mechanical pumps or any of the hydronic water for filling; if external pumps are needed, include velocity and head requirements for the temporary pump that the contractor should use or rent.

A. The following applies to all temporary and permanent HVAC piping installation, both aboveground and underground. All of the following items must be completed prior to placing new connected HVAC pipes into operation with existing and/or new piping systems. The following items apply to Condenser-Water piping, Chilled-Water piping, Dual-Temperature Heating and Cooling Water Piping, and Hot-Water Heating Piping systems. All piping and related equipment shall be thoroughly flushed out with pre-cleaning chemicals designed to remove deposits such as pipe dope, oils, loose rust, mill scale, and other extraneous-materials.

B. Use clean potable water source. If not available from the Airport’s water supply, then the Contractor must provide his own source of clean potable water. If high volumes of water are to be drawn from the Airport’s water supply system, then the Contractor will provide a strainer to remove sand and grit which may be drawn from this water supply system.

C. All temporary connections are required for cleaning, purging, and circulating shall be included. Provide suitable pipe bypasses at each coil and heat exchanger during this cleaning operation.

D. The Contractor shall provide temporary pumps and strainers with fine mesh screens to obtain minimum eight (8) feet per second flushing velocity within the HVAC piping systems.

1. It may be possible to use existing pumps in the HVAC System, or pumps which are new as part of this project to obtain the minimum eight feet per second flushing velocity. If the Contractor wishes to utilize any new pumps or existing pumps within the HVAC piping system to obtain the minimum flushing velocity, this must be approved by the DEN Mechanical Engineer, DEN CUP Supervisor and the DEN Project Manager.

2. The Contractor shall provide additional fine mesh screens to insert into the existing strainers during flushing operations if allowed by DEN.

3. The Contractor shall provide temporary cone filters/strainers installed between two pipe flanges in the inlet piping to large equipment upstream of any control valves where there are no strainers included in the design.
4. Once the flushing is complete, the temporary strainers will be replaced with new strainer inserts matching existing and/or new pumps as utilized.
5. If the new or existing pumps are used, the Contractor shall replace all pump seals after flushing operations, and then provide an additional set of pump seals for Maintenance's use

E. During the flushing operation, the Contractor shall add chemicals (cleaning agent) as necessary to clean all piping process oils and dirt/debris from within the piping systems. These chemicals shall not harm the new piping systems and any connected piping systems, including all valves, pumps, equipment, seals, gaskets, and other items associated with the piping systems. All cleaning agents subject to approval by DEN Environmental, the DEN CUP Supervisor and the DEN Project Manager.

F. The cleaning operation for each section of piping installed shall be for a minimum of three (3) hours, or as necessary to completely clean all pipes. This water shall then be drained.

1. Pre Flush - Bypass loops should be installed at all equipment components. Strainers can be removed when a self-contained purge unit is used in conjunction with on board filtration. Flush ports should be identified along with the type of high pressure hose or piping that will be used to connect to the system. The water source should be identified and must be adequate to fill and make up water in a timely manner to the system during the flush process.
2. Clear Water Flush – Fill the piping system with clean potable water. The first flush is a clearwater flush intended to circulate water through the system and force loose debris to low point drains and the flush cart filtration system. This flush should be at minimum velocity throughout the system of 5 to 7 ft/sec. Filtration should be 25 micron. Once drained, the piping shall be flushed with clean potable water until no foreign matter is observed and total alkalinity of the rinse water is equal to or better than that of the make-up water.
3. Cleaning & Passivation - The second flush cycle is a combined flushing cycle where cleaning and passivation chemicals are introduced into the system to clean the oils and treat the inside wall of the piping system. The cleaning velocity should be between 3 to 5 ft/sec and the circulation time will be based on the chemical testing but will typically be up to 48 hours.
4. Treatment – After cleaning and before adding chemical initial charge, system must be flushed to meet these minimum requirements:
   a. Conductivity no higher than 20 mmho above domestic water level
   b. No foam
   c. Copper level less than 0.5 ppm
   d. Iron level less than 1.0 ppm
   e. pH 9.4 or less
   f. Less than 1 ppm phosphates (ortho-phosphate PO_4)
5. Final Clear Water Flush – The system will be continuously flushed while discharging chemicals into the sanitary system as approved by DEN. As the existing treated water is being discharged a fresh water make-up source will be utilized to ensure air is not introduced into the system. Continue to drain the system while adding domestic water to dilute the treated water. Flush with fresh water until the conductivity is reduced to that of the make-up water and iron level is 1.0 ppm or less. Filtration should be 5 micron.
6. Final Chemical Fill – Once the system has been brought back to the correct composition, provide chemicals (match existing chemicals used by DEN) to bring new piping additions and existing piping system which are affected back to existing Central Plant Piping system chemical level conditions. Coordinate introduction and verification of chemical concentrations with the DEN CUP Supervisor. Once the system is filled with the final chemicals it is important that the water is not to be left stagnant. Chemical treatment shall be comparable to existing treatment program.

G. System flushing and cleaning shall be witnessed by DEN Mechanical Inspector, DEN Project Manager and/or a DEN appointed representative. Provide a written request for the witness a minimum of 72 hours prior to cleaning. Verify satisfactory completion of clean pipe and a final flushing and chemical treatment report should be signed by field personnel and submitted.

H. For underground pipes (when allowed) are installed, prior to flushing the piping systems as described above, the Contractor shall provide television inspection of the entire pipe installation. This can be accomplished as the pipes are installed in several hundred foot sections (or the limit of the camera equipment used by the Contractor). The Contractor shall provide DVDs of the pipe interiors to show that no (or very minimal) excavation and backfill dirt has entered the piping systems. Two copies of these pipe inspections shall be provided to the DEN Project Manager. The DVDs should clearly indicate the date, time, and section of piping being videoed. If these DVDs indicate that there are large amounts of debris within the piping system, the DEN Project Manager may either direct the Contractor to open the pipes in the areas of question and clean them out or have the Contractor re-record the pipe sections after the pipes are flushed. This will be at no additional cost to DEN.

I. The above noted items are minimum requirements for the Contractor to complete to clean and flush the HVAC piping systems. The Contractor is fully responsible for a satisfactory flushing operation. Any damage to existing pumps, boilers, chillers, cooling towers, control valves, coils and other associated items within the piping systems due to poor flushing and cleaning of the piping systems will be the responsibility of the Contractor. The Contractor shall make all necessary repairs at no additional cost to DEN.

J. Contractor is to provide DEN photographic evidence of the cleaning process. Photographs are to include photos of the temporary screens in hydronic equipment strainers after each phase of the process. Where blow-down of strainers is used during the cleaning process for VAV Air Terminals, Unit Heaters, Cabinet Unit Heaters and Air-Handling Units below 2,500 CFM, contractor shall photograph the contents of the strainer effluent after each phase of the cleaning process.

Section 230500: Common Work Results for HVAC Equipment

Engineer to include all aspects of this specification section though out the project specifications. This section includes aspects that are common to multiple sections.

PART 1 GENERAL

1.01 SUMMARY

A. This Section includes the following basic mechanical materials and methods to complement other Division 23 Sections.

1.02 DEFINITIONS

A. Pipe, pipe fittings, and piping include tube, tube fittings, and tubing.

B. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe and duct shafts, unheated spaces immediately below the roof, spaces above ceilings, unexcavated spaces, crawl spaces, and tunnels.

C. Exposed Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.

D. Exposed Exterior Installations: Exposed to view outdoors, or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.

E. Concealed Interior Installations: Concealed from view and protected from physical contact by building occupants. Examples include above ceilings and in duct shafts.

F. Concealed Exterior Installations: Concealed from view and protected from weather conditions and physical contact by building occupants, but subject to outdoor ambient temperatures. Examples include installations within unheated shelters.

1.03 SUBMITTALS

Delegated design of vibration isolators, pipe expansion, pipe supports, equipment supports, etc. and associated attachments is not allowed at DEN. Engineer is responsible for providing the necessary details needed for the scope of work. Remove all references to delegated design of these items from Specifications.

A. Delegated-Design Submittal: For air-cooled refrigerant condensers indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
2. Design Calculations: Calculate requirements for selecting vibration isolators and for designing vibration isolation bases.

B. General: Submit the following according to the Conditions of the Contract and DEN specification Division 01 Specification Sections:

1. Product Data: For each type of product indicated.
   a. Submit manufacturer's technical product data and installation instructions for system materials and products.
   b. Include data substantiating that materials comply with requirements.
   c. Provide component sizes, rough-in requirements, service sizes, and finishes.
2. Shop drawings referenced in Section 230400.

Coordinate requirements for coordination drawings with DEN Project Manager.

3. Prepare coordination drawings according to Division 01 Section 013300 “Submittals” to a 1/4 inch equals 1 foot scale or larger for approval by DEN Mechanical Engineer prior to start of work. Detail major elements, components, and systems of mechanical equipment and materials in relationship with other systems, installations, and building components. Show space requirements for installation and access. Show where sequence and coordination of installations are important to the efficient flow of the Work. Include the following:
   a. Clearances for servicing and maintaining equipment, including space for equipment disassembly required for periodic maintenance.
   b. Pump metal support details.
   c. Include diagrams for power, signal, and control wiring.
   d. For fabricated items, indicate dimensions, weights, and placement of openings and holes.
   e. Include plans, elevations, sections, and details.
   f. Show piping materials, size, locations, and elevations.
   g. Detail fabrication of pipe anchors, alignment guides, expansion joints and loops, and their attachment to the building structure.
   h. Indicate location of anchors, alignment guides, and expansion joints and loops.
   i. Include details of structures, and connections. Show interface and spatial relationship between ductwork, piping and proximate structures.
   j. Duct installation in congested spaces, indicating coordination with general construction, building components, and other building services. Indicate proposed changes to duct layout.
   k. Suspended ceiling components.

l. Structural members to which duct, pipe and equipment will be attached.
m. Size and location of initial access modules for acoustical tile.
n. Other systems installed in same space as ducts.
o. Ceiling- and wall-mounting access doors and panels required to provide access to dampers and other operating devices.
p. Ceiling-mounting items, including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.
q. Penetrations of smoke barriers and fire-rated construction.
r. Items penetrating finished ceiling including the following:
1. Lighting fixtures.
2. Air outlets and inlets.
3. Speakers.
4. Sprinklers.
5. Access panels.

4. Welder certificates signed by Contractor certifying that welders comply with requirements specified under the Quality Assurance Article.
5. Floor x-rays and/or ground penetrating radar reports.
6. All documents shall be submitted in electronic format. Each submittal shall be in a single security free PDF document. PDF documents shall be compatible with Adobe Acrobat 10.0 or newer. All as-built documents shall be submitted in Revit in accordance with DEN specification Division 1 requirements.

Do not delete spool drawings paragraph if welded piping is used.

7. Contractor shall submit fully dimensioned spool drawings for approval from DEN Mechanical Engineer prior to start of fabrication for all welded piping work. Drawings shall indicate all weld types, sizes and materials to be used. The spool drawing size shall match the full-size contract documents of either 24"x36" or 34"x44". Spool drawings shall be submitted in electronic format in Revit in compliance with DEN specification Division 1 requirements. Files shall not contain security. Other file formats will not be accepted. This requirement is for welded piping only and is used for the ITA and DEN quality assurance personnel.
8. Field Test Reports: Written reports of each pressure tests specified in Division 23 Sections. Include the following:
a. Test procedures used.
b. Test results that comply with requirements.
c. Failed test results and corrective action taken to achieve requirements.
9. Multiple Submissions:
a. If multiple submissions are required to execute work within schedule, first submit a coordinated schedule clearly defining intent of multiple submissions. Include a proposed date of each submission with a detailed description of submittal content to be included in each submission.
b. Clearly identify each submittal requirement indicated and in which submission the information will be provided.
c. Include an updated schedule in each subsequent submission with changes highlighted to easily track the changes made to previous submitted schedule.

1.04 QUALITY CONTROL

A. Equipment Selection: Equipment of greater or larger power, dimensions, capacities, and ratings may be furnished provided such proposed equipment is approved in writing by the DEN Project Manager and connecting mechanical and electrical services, circuit breakers, conduit, motors, bases, and equipment spaces are increased. No additional costs will be approved for these increases, if larger equipment is approved. If minimum energy ratings or efficiencies of the equipment are specified, the equipment must meet the design requirements and commissioning requirements.

B. Electronic Equipment Compliance:

1. Contractor warrants that all equipment, devices, items, systems, software, hardware, or firmware provided shall properly, appropriately, and consistently function and accurately process date and time data (including without limitation: calculating, comparing, and sequencing). This warranty supersedes anything in the Specifications or other Contract Documents which might be construed inconsistently. This warranty is applicable whether the equipment, device, item, system, software, hardware, or firmware is specified with or without reference to a manufacturer's name, make, or model number.

C. Unless specified otherwise, all materials and equipment shall be of domestic (USA) manufacture and shall be of the best quality used for the purpose in commercial practice.

D. Insulation shall be applied by mechanics skilled in the work and regularly engaged in such occupation. All insulation shall be applied in strict accordance with manufacturer's recommendations and installation instructions as applicable. Unsightly or inadequate work will not be acceptable, and all such work shall be removed and replaced as necessary to achieve an acceptable installation.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Deliver pipes and tubes with factory-applied end-caps. Maintain end-caps through shipping, storage, and handling to prevent pipe-end damage and prevent entrance of dirt, debris, and moisture.

B. Protect stored ductwork, pipes, and tubes from moisture and dirt. Elevate above grade. When stored inside, do not exceed structural capacity of the floor.

C. Store plastic pipes protected from direct sunlight. Support to prevent sagging and bending.

D. Protect flanges, fittings, and piping specialties from moisture and dirt.

E. Deliver ductwork and fittings with plastic sheeting to protect it from elements. Inspect duct liner for exposure to dirt and tears.

1.06 SEQUENCING AND SCHEDULING

A. Coordinate mechanical equipment installation with other building components.

B. Coordinate the installation of required supporting devices.

C. Sequence, coordinate, and integrate installations of mechanical materials and equipment for efficient flow of the Work.

D. Coordinate connection of electrical services.

E. Coordinate installation of identifying devices after completing covering and painting where devices are applied to surfaces.

PART 2 PRODUCTS

2.01 JOINING MATERIALS

Grooved Mechanical Couplings: Acceptable only for fire protection piping; not acceptable for any other applications.

Push-on or press-on types of connectors are not allowed.

A. Pipe Flange Gasket Materials: Suitable for the chemical, pressure, and thermal conditions of the piping system contents.

1. ASME B16.21, nonmetallic, flat, asbestos-free, 1/8-inch maximum thickness, except where thickness or specific material is indicated.
   a. Full-Face Type: For flat-face, Class 125 cast-iron and cast-bronze flanges.
   b. Narrow-Face Type: For raised-face, Class 250 cast-iron and steel flanges.

B. Solder Filler Metal: ASTM B 32.

1. Alloy Sn95 or Alloy Sn94: Tin (approximately 95 percent) and silver (approximately 5 percent) – Not industry standard, usually 5% antimony.

C. Brazing Filler Metals: AWS A5.8.

1. BCuP Series: Copper-phosphorus alloys.
2. BAg1: Silver alloy.

D. Welding Filler Metals: Comply with AWS D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded. All welding rod is to be kept in an operable rod oven at all times

2.02 BACKFILL

A. Flowable Backfill: Designed in accordance with ASTM C 94 and ASTM D 4832.

1. Refer to Section 033350 "Flowable Backfill Low-Strength Concrete" for material and installation requirements.
2. Minimum Requirements:
   a. Compressive Strength: 50-100 psi
   b. Slump: 6-8 inches.
3. Required for all piping installed below concrete slabs, apron paving, and roadways.

B. Other methods of backfill for these areas is prohibited. No exceptions will be allowed.

C. Coordinate requirements for flowable backfill with requirements of Denver Water.

2.03 CONTROLS

A. BACnet MSTP/IP communication interface with the DDC system for HVAC shall enable the DDC system for HVAC operator to remotely control and monitor the unit from an operator workstation. Control features and monitoring points displayed locally at unit control panel shall be available through the DDC system for HVAC accessories.

2.04 UNIT CONTROL PANEL

A. Controls shall be provided by the controls contractor and NOT factory provided unless specifically approved.

B. All BACnet controllers shall be fully open programmable controllers (not ASC controllers) unless specifically approved.

2.05 AIR HANDLING UNIT CONTROLS

A. DDC Temperature Control: Shall be BACnet/ MTSP and provided by the Controls Contractor (factory- not preferred). Shall be able to operate in a standalone control mode in the event of a network outage. Control module shall be compatible with control system specified in Section 230923 “Direct Digital Control (DDC) System for HVAC.” Links shall include the following:

1. Hardware interface or additional sensors including but not limited to the following:
   a. Room temperature.
   b. Discharge-air temperature.

c. Refrigeration system operating.
d. Furnace operation.
e. Constant and variable motor loads.
f. Variable-frequency-controller operation.
g. Cooling load.
h. Economizer cycles.
i. Air-distribution static pressure and ventilation-air volumes.
j. Unit start/stop status.

2.06 OUTDOOR EQUIPMENT ACCESSORIES

A. Service Platform: Steel or Galvanized steel or Aluminum, minimum 42 inches wide running entire length of unit and located on service access side, with angle side rails, 4-inch kick plates, and expanded metal floor. Provide platform with a fixed ladder that extends from the top of the side rail to the floor.

B. Lighting: Provide vapor-proof incandescent lights with guards in each accessible maintenance area. Include weatherproof switches with pilot lights on outside surface of casing for control of lighting

PART 3 EXECUTION

3.01 INSTALLATION REQUIREMENTS

A. Install in accordance with manufacturers written instructions.

B. Coordinate to assure correct recess size for recessed units.

C. Install equipment exposed to finished areas after walls and ceiling are finished and painted. Avoid damage to other materials.

D. Protection: Provide finished units with protective covers during balance of construction.

3.02 SOUND PERFORMANCE REQUIREMENTS

More specific DEN Sound requirements can be found in section 1.1.6. Design shall conform to these requirements, as well as those listed below.

A. Radiated noise shall not exceed:

1. NC 35 – In Office.
2. NC 40 – Terminal/Concourse.
3. NC 45 – Maintenance Facilities.

3.03 PIPING SYSTEMS- COMMON REQUIREMENTS

A. PREPARATION

1. Ream pipe and tube ends. Remove burrs.
2. Remove scale and dirt, on inside and outside, before assembly.
3. Prepare piping connections to equipment with flanges or unions.

B. Install piping at indicated slope.

C. Install piping free of sags and bends.

D. Install piping plumb and at right angles and plumb or parallel to building walls. Diagonal runs are prohibited, except where indicated.

E. Install piping tight to slabs, beams, joists, columns, walls, and other building elements.

F. Install fittings for changes in direction and branch connections.

G. Piping Connections: Except as otherwise indicated, make piping connections as specified below.

1. Install unions in piping 2 inches and smaller adjacent to each valve and at final connection to each piece of equipment having a 2-inch or smaller threaded pipe connection.
2. Wet Piping Systems: Install dielectric coupling and nipple fittings to connect piping materials of dissimilar metals.
3. Install piping adjacent to machine to allow service and maintenance.
4. Unless otherwise indicated, install shutoff valve and union or flange at each connection.
5. Make hydronic connections to coils, valves, and equipment with unions and flanges.
6. Install coils level. Install cleanable tube coils with 1:50 pitch when used.
7. Install coils in metal ducts and casings constructed according to SMACNA's “HVAC Duct Construction Standards, Metal and Flexible.”
   a. Support coil sections independent of piping on steel channel or double angle frames and secure to casings.
   b. Provide frames for maximum three coil sections.
   c. Arrange supports to avoid piercing drain pans.
   d. Install coil to assure access for cleaning and maintenance.
   e. Provide airtight seal between coil and duct or casing.
8. Connect water supply to leaving air side of coil (counterflow arrangement).
9. Provide shut-off valve on supply line and lockshield balancing valve with memory stop on return line.
   a. Balancing valves are not required where control valves also act as balancing valves.
10. Locate water supply at bottom of supply header and return water connection at top.
11. Provide float operated automatic air vents at high points complete with stop valve. Pipe the vent to drain.
12. Ensure water coils are drainable and provide drain connection at low points.
13. Connect condensate drain to indirect waste.
14. It is not allowable to install flange connections in the pipe run in the absence of an inline flanged component or equipment termination.
15. It is not allowable to install additional valves in a system beyond what is indicated without written permission from the DEN Project Manager or DEN Mechanical Engineer. Incremental testing of piping systems to be avoided unless permission is given from the DEN Project Manager.
16. Torque flange bolts as recommended by manufacturer
   a. DEN Project Manager, DEN Mechanical QA Inspector, DEN Mechanical Engineer or their designated representative(s) shall randomly select a minimum of 10% of the flanges installed to verify the torque on the flange bolts.
   b. The contractor shall furnish a representative with the appropriate tools for the inspection. If a torque falls to more than 10% below required value, the flange torques shall constitute a failure and all bolts will be re-torqued by the contractor. Rechecking shall be limited to either 10% of the total flanges, or the extent of measurements that can be accomplished in a normal 8-hour business day.
   c. Notify the DEN Project Manager, and DEN Mechanical QA Inspector in writing a minimum of 72 hours prior to testing of any flange bolt torques for mechanical equipment and systems if no shutdown request is required.

H. Piping below apron, concrete slabs or paving shall be encased in flowable backfills.

I. Install manual air vents at high points of system and drains, consisting of a tee fitting, NPS 3/4 ball valve, and short NPS 3/4 threaded nipple with cap, at low points in piping system mains and elsewhere as required for system drainage. Air vents located more than 15'-0" AFF shall have valve piped to accessible location no more than 8'-0" AFF.

J. Install piping to permit valve servicing.

3.04 EQUIPMENT INSTALLATION- COMMON REQUIREMENTS

A. Install equipment to provide the maximum possible headroom where mounting heights are not indicated.

B. Install equipment according to approved submittal data. Portions of the Work are shown only in diagrammatic form. Refer conflicts to the DEN Project Manager.

C. Install equipment level and plumb, parallel and perpendicular to other building systems and components in exposed interior spaces, except where otherwise indicated.

D. Install mechanical equipment to facilitate servicing, maintenance, and repair or replacement of equipment components. Connect equipment for ease of disconnecting, with minimum of interference with other installations. Extend grease fittings to an accessible location.

E. Install equipment giving right-of-way to piping systems installed at a required slope.

F. Electrical Connections

1. Ground equipment.
2. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.

3.05 VALVE INSTALLATION

A. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.

B. Provide dielectric fittings wherever jointing dissimilar metals.

C. Locate valves for easy access and provide separate support where necessary.

D. Provide clearance for installation of insulation and access to valves and fittings.

E. Provide access where valves and fittings are not exposed. Coordinate size and location of access doors with Division 08 installer.

F. Install valves with stems upright or horizontal, not inverted.

G. Lever Handle Valves: Install valve handle so that the handle opens in the direction of fluid flow.

H. Install valves in horizontal piping with stem at or above center of pipe.

I. Install valves in position to allow full stem movement.

J. Install chainwheels on operators for butterfly, globe, and plug valves NPS 4 and larger and more than 96 inches above floor. Extend chains to 60 inches above finished floor. Include chain-up device and safety restraint system for valves using chainwheels.

K. Install check valves for proper direction of flow and as follows:

1. Swing Check Valves: In horizontal position with hinge pin level.
2. Center-Guided and Plate-Type Check Valves: In horizontal or vertical position, between flanges.
3. Lift Check Valves: With stem upright and plumb.

L. Install valve tags. Comply with requirements in Section 230553 “Identification for HVAC Piping and Equipment” for valve tags and schedules.

3.06 GENERAL REQUIREMENTS FOR VALVE APPLICATIONS

Engineer to verify that valve classes and pressure-temperature ratings are adequate for system fluid. Indicate location of each different pressure system on Drawings.

A. If valves with specified SWP classes or CWP ratings are unavailable, the same types of valves with higher SWP classes or CWP ratings may be substituted.

B. Select valves with the following end connections:

1. For Copper Tubing, NPS 2 and Smaller: Threaded ends except where solder-joint valve-end option is indicated in design documents.
2. For Copper Tubing, NPS 2-1/2 to NPS 4: Flanged ends except where threaded valve-end option is indicated in design documents.
3. For Copper Tubing, NPS 5 and Larger: Flanged ends.
4. For Steel Piping, NPS 2 and Smaller: Threaded ends.
5. For Steel Piping, NPS 2-1/2 to NPS 4: Flanged ends except where threaded valve-end option is indicated in design documents.
6. For Steel Piping, NPS 5 and Larger: Flanged ends.

3.07 PAINTING AND FINISHING

Division 09 sections specify paint products for various surfaces (e.g., ferrous and nonferrous metals and insulation jackets), items to be field painted, application methods, and coating systems (number of prime and finish coatings and coating thicknesses). Coordinate these requirements with Architect to ensure that appropriate painting requirements are retained in these Division 09 sections.

A. Paint color schedule shall conform to ASME A13.1-1996," Scheme for the Identification of Piping Systems."

B. Damage and Touch Up: Repair marred and damaged factory-painted finishes with materials and procedures to match original factory finish.

C. All rooftop equipment exposed to public or aircraft view shall be painted flat white or grey in accordance with Division 09.

3.08 CONCRETE PENETRATIONS

DEN specification Division 01 and Division 02 Sections have specific requirements for x-raying and GPR. Coordinate the paragraphs below with Project and other specification Sections.

Reference DEN Specifications Section 017330 "Cutting and Patching" for core drilling and saw cutting requirements.

Reference DEN Specifications Section 024119 "Selective Demolition" for demolition and removal of selected portions of a building or structure, and repair procedures for selective demolition operations.

A. All penetrations required through completed concrete construction shall be core drilled or saw cut at minimum size required. All penetrations in concrete require an x-ray or ground penetrating radar to determine if the location is clear of reinforcing steel and embedded systems. Precautions shall be taken when drilling to prevent damage to structural concrete.

1. The Contractor shall provide an interpretation of the x-rays or radar shot and obtain written acceptance from the DEN Project Manager before proceeding with drilling.

3.09 WELDING

Where welding is required for framing of openings, drain pans, or duct-pipe supports, DEN Specifications Section 050510 "Welding" shall be included. No exceptions. The following paragraphs shall be included in the specifications:

A. Qualify welding processes and operators for structural steel according to AWS D1.1/D1.1M Structural Welding Code- Steel. Additional standards include:

1. AWS D1.2.
2. AWS D1.3.
3. AWS D1.4.
4. See Division 05 for additional requirements.

B. All welding shall be inspected in process by a contractor-provided, Certified, Independent Testing Agency by an AWS certified welding inspector.

C. Qualify welding processes and operators for piping according to ASME Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications.

1. Comply with provisions of ASME B31 Series “Code for Pressure Piping.”
2. Certify that each welder has passed AWS qualification tests for the welding processes involved and that certification is current.

3.10 ERECTION OF METAL SUPPORTS AND ANCHORAGE

No steel shall be generally specified on the drawings. Include the appropriate Division 05 specifications.

A. Cut, fit, and place miscellaneous metal supports accurately in location, alignment, and elevation to support and anchor mechanical materials and equipment.

B. Field Welding: Comply with AWS D1.1 Structural Welding Code- Steel.

3.11 ERECTION OF WOOD SUPPORTS AND ANCHORAGES

Wood supports are only allowed in roof equipment curbs. All supports inside the building shall be constructed entirely of metal.

Engineer to include details for attachment of roof equipment to the roof curb and the roof curb to the roof.

A. Cut, fit, and place wood grounds, nailers, blocking, and anchorages to support, and anchor mechanical materials and equipment.

B. Select fastener sizes that will not penetrate members if opposite side will be exposed to view or will receive finish materials. Tighten connections between members. Install fasteners without splitting wood members.

C. Attach to substrates as required to support applied loads.

3.12 ENVIRONMENTAL REQUIREMENTS

A. Maintain ambient temperatures and conditions required by manufacturers of adhesives, mastics, and insulation cements.

B. Maintain temperature during and after installation for minimum period of 24 hours.

3.13 CLEANING

A. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.

B. Touch-up marred or scratched surfaces of factory-finished components, using finish materials furnished by manufacturer.

C. Clean coils using materials and methods recommended in writing by manufacturers, and clean inside of casings and enclosures to remove dust and debris.

D. Install new filters

3.14 DEMOLITION

DEN has specific demolition restrictions. Coordinate requirements of this Section with DEN specification Division 01 and Division 02 and DEN Project Manager

A. Where pipe, insulation, or equipment to remain is damaged or disturbed, remove damaged portions and install new products of equal capacity and quality.

B. Temporary Disconnection: Remove, store, clean, reinstall, reconnect, and make operational equipment indicated for relocation.

C. Disconnect, demolish, and remove Division 23 systems, equipment, and components indicated to be removed.

1. Piping to Be Removed: Remove portion of piping and associated supports indicated to be removed, provide a shutoff valve with plug or cap in pressurized systems and cap or plug remaining piping with same or compatible piping material. No piping shall be abandoned in place. Repair insulation.
2. Equipment to Be Removed: Disconnect and cap services and remove equipment.
3. Equipment to Be Removed and Reinstalled: Disconnect and cap services and remove, clean, and store equipment; when appropriate, reinstall, reconnect, and make equipment operational.
4. Equipment to Be Removed and Salvaged: Disconnect and cap services and remove equipment and deliver to DEN Project Manager.
5. If pipe, insulation, or equipment to remain is damaged in appearance or is unserviceable, remove damaged or unserviceable portions and replace with new products of equal capacity and quality.
6. Repair structure floor, ceilings, roof, slabs from removed supports in accordance with
7. Division 03, Division 05, and Division 09 as required for the project.

3.15 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain heating and ventilating units.

B. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

3.16 STARTUP SERVICE

A. Engage a factory-authorized service representative to assist Contractor and perform startup service.

3.17 FIELD QUALITY CONTROL

A. Retest as specified above after repairs or replacements are made.

3.18 ADJUSTING

A. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide four (4) visits to Project during other-than-normal occupancy hours for this purpose.

Section 230516: Expansion Fittings and Loops for HVAC Piping

All equipment supports and thermal expansion compensation shall be manufactured systems or designed and detailed by a Colorado Registered Professional Engineer. Supports shall be coordinated with Architectural and Structural disciplines.

Under no circumstances shall the construction documents direct a Contractor to provide supports without detailed performance specifications outlining criteria and requirements of supports and their design and installation.

Delegated design of expansion fittings and loops for HVAC Piping is not allowed at DEN. Engineer is responsible for providing design for size, location, supports, etc. Remove all references to delegated design of expansion fittings and loops for HVAC Piping from Specifications.

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Product Data: For each type of product indicated, and as follows:

1. Include data substantiating that materials comply with requirements.
2. Flexible Pipe Connectors: Indicate maximum temperature and pressure rating, face-to-face length, live length, hose wall thickness, hose convolutions per foot and per assembly, fundamental frequency of assembly, braid structure, and total number of wires in braid.
3. Expansion Joints: Indicate maximum temperature and pressure rating, and the estimated number of full flexures before joint failure. Provide multi-wall convoluted bellows where possible to reduce joint end force reactions on building structure.

B. Shop Drawings:

1. Expansion Joints: Submit for each assembly shop drawings, along with procedures applied in making selections as appropriate to lifetime cycles ratings specified. Identify materials of construction and indicate maximum temperature and pressure ratings.

PART 2 PRODUCTS

Engineer to select apparatus that exceed required test pressures and operational temperatures. Verify that specified items meet these requirements. Indicate both operational and test pressures, basis of design pressure and corresponding temperature, and operational temperatures for each apparatus in the specifications or schedule in the Construction of Documents.

Engineer to select metal bellows type of flex connectors for connections to pumps or equipment 4" in diameter or larger. Stainless-steel braided connectors to be used only with permission from DEN Mechanical Engineer and shall not have rubber sleeves. Rubber types of flex connectors are not allowed. Flex connectors are to include control rods.

Engineer to select braided stainless-steel flex connectors for connections to equipment smaller than 4" in diameter. Braided stainless-steel connectors are not to include rubber internal sleeves.

PART 3 EXECUTION

3.01 INSPECTION

A. Examine piping layout and notify DEN Project Manager of additional anchors or expansion joints required to adequately protect system.

B. Provide inspection services by flexible pipe manufacturer's representative for final installing and certify installation is in accordance with manufacturer's recommendations and connectors are performing satisfactorily.

Section 230517: Sleeves and Seals for HVAC Piping

PART 1 GENERAL

PART 2 PRODUCTS

Where Engineer is presented with choices between silicone sealant and grout, Engineer shall select grout.

PART 3 EXECUTION

Section 230519: Meters and Gauges for HVAC Piping

PART 1 GENERAL

1.01 ENVIRONMENTAL REQUIREMENTS

A. Do not install instrumentation when areas are under construction, except for required rough-in, taps, supports and test plugs.

PART 2 PRODUCTS

All electronic meters connected to the EMCS shall be BACnet-compatible.

2.01 DUCT-THERMOMETER MOUNTING BRACKETS

A. Socket: Brass separable sockets for thermometer stems with extensions where necessary to clear insulation, and with cap and chain.

B. Description: Flanged bracket with screw holes, for attachment to air duct and made to hold thermometer stem.

1. Flange: 3-inch outside diameter reversible flange, designed to fasten to sheet metal air ducts, with brass perforated stem.

Orifice, Pitot-Tube, Venturi, and Vortex-Shedding Flowmeters are not allowed at den without written permission from DEN Mechanical Engineer. remove all flow meter types except for turbine flow meters from specifications.

Impeller-Turbine Thermal Energy meters shall be used in all applications where piping is sufficiently sized, except with written permission from DEN Mechanical Engineer.

PART 3 EXECUTION

3.01 INSTALLATION

A. Install in accordance with manufacturer's instructions.

B. Install positive displacement meters with isolating valves on inlet and outlet. Provide full line size valved bypass with globe valve for liquid service meters.

C. Provide one pressure gauge per pump. Install taps before strainers and on suction and discharge of pumps and manifold to a single pressure gauge with an isolation valve for each leg of the manifold.

D. Install pressure gauges with pulsation dampers. Provide needle valve to isolate each gauge. Extend nipples to allow clearance from insulation.

E. Install thermometers in piping systems in sockets in short couplings. Enlarge pipes smaller than 2-1/2 inch for installation of thermometer sockets. Ensure sockets allow clearance from insulation.

F. Install thermometer sockets adjacent to controls systems thermostat, transmitter, or sensor sockets. Where thermometers are provided on local panels, duct or pipe mounted thermometers are not required.

G. Locate duct mounted thermometers minimum 10 feet downstream of mixing dampers, coils, or other devices causing air turbulence.

H. Coil and conceal excess capillary on remote element instruments.

I. Provide instruments with scale ranges selected according to service with largest appropriate scale.

J. Install gauges, thermometers and test plug in locations where there is an unobstructed field of view from a normal operating level. All portions of gauges and thermometers shall be easily read from a normal operating level. Locations of test plugs shall be treated as a gauges or thermometers for installation and field of view verification.

K. Install Pressure and Temperature plugs:

1. Inlet and outlet of all coils.
2. Pump suction and dishcarge

Insert any other locations for P-T plug installation.

3.02 FLOWMETER SCHEDULE

All Flowmeters shall be Turbine type, except with written permission from DEN Mechanical Engineer.

3.03 THERMAL-ENERGY METER SCHEDULE

All Thermal-Energy Meters shall be Impeller-Turbine type, except with written permission from DEN Mechanical Engineer.

Section 230523.11: Globe Valves for HVAC Piping

For all valves installed at DEN, end connections shall be either threaded or flanged. Remove all other end-connection types from specifications.

PART 1 GENERAL

1.01 QUALITY ASSURANCE

A. Source Limitations for Valves: Obtain each type of valve from single source from single manufacturer.

B. Refer to HVAC valve schedule articles for applications of valves.

PART 2 PRODUCTS

All valves shall be metal and shall be made of the same material as the attached piping. Where products are not available in the same metal as the piping that meet specification requirements, dielectrics shall be used at all joints between dissimilar materials.

PART 3 EXECUTION

3.01 PREPARATION

A. Ream pipe and tube ends. Remove burrs.

B. Remove scale and dirt, on inside and outside, before assembly.

C. Prepare piping connections to equipment with flanges or unions.

3.02 VALVE INSTALLATION

A. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.

B. Provide dielectric fittings wherever jointing dissimilar metals.

C. Locate valves for easy access and provide separate support where necessary.

D. Provide clearance for installation of insulation and access to valves and fittings.

E. Provide access where valves and fittings are not exposed. Coordinate size and location of access doors with Division 08 installer.

F. Install valves with stems upright or horizontal, not inverted.

G. Lever Handle Valves: Install valve handle so that the handle opens in the direction of fluid flow.

H. Install valves in horizontal piping with stem at or above center of pipe.

I. Install valves in position to allow full stem movement.

J. Install chainwheels on operators for globe valves NPS 4 and larger and more than 96 inches above floor. Extend chains to 60 inches above finished floor. Include chain-up device and safety restraint system for valves using chainwheels.

K. Install valve tags. Comply with requirements in Section 230553 "Identifications for HVAC Piping and Equipment" for valve tags and schedules.

Section 230523.12: Ball Valves for HVAC Piping

For all valves installed at DEN, end connections shall be either threaded or flanged. Remove all other end-connection types from specifications.

PART 1 GENERAL

1.01 QUALITY ASSURANCE

A. Source Limitations for Valves: Obtain each type of valve from single source from single manufacturer.

B. Refer to HVAC valve schedule articles for applications of valves.

PART 2 PRODUCTS

All valves shall be metal and shall be made of the same material as the attached piping. Where products are not available in the same metal as the piping that meet specification requirements, dielectrics shall be used at all joints between dissimilar materials.

PART 3 EXECUTION

3.01 PREPARATION

A. Ream pipe and tube ends. Remove burrs.

B. Remove scale and dirt, on inside and outside, before assembly.

C. Prepare piping connections to equipment with flanges or unions.

3.02 VALVE INSTALLATION

A. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.

B. Provide dielectric fittings wherever jointing dissimilar metals.

C. Locate valves for easy access and provide separate support where necessary.

D. Provide clearance for installation of insulation and access to valves and fittings.

E. Provide access where valves and fittings are not exposed. Coordinate size and location of access doors with Division 08 installer.

F. Install valves with stems upright or horizontal, not inverted.

G. Lever Handle Valves: Install valve handle so that the handle opens in the direction of fluid flow.

H. Install valves in horizontal piping with stem at or above center of pipe.

I. Install valves in position to allow full stem movement.

J. Install chainwheels on operators for globe valves NPS 4 and larger and more than 96 inches above floor. Extend chains to 60 inches above finished floor. Include chain-up device and safety restraint system for valves using chainwheels.

K. Install valve tags. Comply with requirements in Section 230553 “Identification for HVAC Piping and Equipment” for valve tags and schedules.

Section 230523.13: Butterfly Valves for HVAC Piping

For all valves installed at DEN, end connections shall be either threaded or flanged. Remove all other end-connection types from specifications.

Butterfly valves are preferred over gate valves in hydronic systems for shutoff duty.

PART 1 GENERAL

1.01 QUALITY ASSURANCE

A. Source Limitations for Valves: Obtain each type of valve from single source from single manufacturer.

B. Refer to HVAC valve schedule articles for applications of valves.

PART 2 PRODUCTS

All valves shall be metal and shall be made of the same material as the attached piping. Where products are not available in the same metal as the piping that meet specification requirements, dielectrics shall be used at all joints between dissimilar materials.

PART 3 EXECUTION

3.01 PREPARATION

A. Ream pipe and tube ends. Remove burrs.

B. Remove scale and dirt, on inside and outside, before assembly.

C. Prepare piping connections to equipment with flanges or unions.

3.02 VALVE INSTALLATION

A. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.

B. Provide dielectric fittings wherever jointing dissimilar metals.

C. Locate valves for easy access and provide separate support where necessary.

D. Provide clearance for installation of insulation and access to valves and fittings.

E. Provide access where valves and fittings are not exposed. Coordinate size and location of access doors with Division 08 installer.

F. Install valves with stems upright or horizontal, not inverted.

G. Lever Handle Valves: Install valve handle so that the handle opens in the direction of fluid flow.

H. Install valves in horizontal piping with stem at or above center of pipe.

I. Install valves in position to allow full stem movement.

J. Install chainwheels on operators for globe valves NPS 4 and larger and more than 96 inches above floor. Extend chains to 60 inches above finished floor.

K. Include chain-up device and safety restraint system for valves using chainwheels.

L. Install valve tags. Comply with requirements in Section 230553 “Identification for HVAC Piping and Equipment” for valve tags and schedules.

Section 230523.14: Check Valves for HVAC Piping

For all valves installed at DEN, end connections shall be either threaded or flanged. Remove all other end-connection types from specifications.

PART 1 GENERAL

1.01 QUALITY ASSURANCE

A. Source Limitations for Valves: Obtain each type of valve from single source from single manufacturer.

B. Refer to HVAC valve schedule articles for applications of valves.

PART 2 PRODUCTS

All valves shall be metal and shall be made of the same material as the attached piping. Where products are not available in the same metal as the piping that meet specification requirements, dielectrics shall be used at all joints between dissimilar materials.

PART 3 EXECUTION

3.01 PREPARATION

A. Ream pipe and tube ends. Remove burrs.

B. Remove scale and dirt, on inside and outside, before assembly.

C. Prepare piping connections to equipment with flanges or unions.

3.02 VALVE INSTALLATION

A. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.

B. Provide dielectric fittings wherever jointing dissimilar metals.

C. Locate valves for easy access and provide separate support where necessary.

D. Provide clearance for installation of insulation and access to valves and fittings.

E. Provide access where valves and fittings are not exposed. Coordinate size and location of access doors with Division 08 installer.

F. Install valves with stems upright or horizontal, not inverted.

G. Lever Handle Valves: Install valve handle so that the handle opens in the direction of fluid flow.

H. Install valves in horizontal piping with stem at or above center of pipe.

I. Install valves in position to allow full stem movement.

J. Install check valves for proper direction of flow and as follows:

1. Swing Check Valves: In horizontal position with hinge pin level.
2. Center-Guided and Plate-Type Check Valves: In horizontal or vertical position, between flanges.
3. Lift Check Valves: With stem upright and plumb.

K. Install valve tags. Comply with requirements in Section 230553 “Identification for HVAC Piping and Equipment” for valve tags and schedules.

Section 230523.16: Plug Valves for HVAC Piping

For all valves installed at DEN, end connections shall be either threaded or flanged. Remove all other end-connection types from specifications.

PART 1 GENERAL

1.01 QUALITY ASSURANCE

A. Source Limitations for Valves: Obtain each type of valve from single source from single manufacturer.

B. Refer to HVAC valve schedule articles for applications of valves.

PART 2 PRODUCTS

All valves shall be metal and shall be made of the same material as the attached piping. Where products are not available in the same metal as the piping that meet specification requirements, dielectrics shall be used at all joints between dissimilar materials.

PART 3 EXECUTION

3.01 PREPARATION

A. Ream pipe and tube ends. Remove burrs.

B. Remove scale and dirt, on inside and outside, before assembly.

C. Prepare piping connections to equipment with flanges or unions.

3.02 VALVE INSTALLATION

A. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.

B. Provide dielectric fittings wherever jointing dissimilar metals.

C. Locate valves for easy access and provide separate support where necessary.

D. Provide clearance for installation of insulation and access to valves and fittings.

E. Provide access where valves and fittings are not exposed. Coordinate size and location of access doors with Division 08 installer.

F. Install valves with stems upright or horizontal, not inverted.

G. Lever Handle Valves: Install valve handle so that the handle opens in the direction of fluid flow.

H. Install valves in horizontal piping with stem at or above center of pipe.

I. Install valves in position to allow full stem movement.

J. Install chainwheels on operators for plug valves NPS 4 and larger and more than 96 inches above floor. Extend chains to 60 inches above finished floor. Include chain-up device and safety restraint system for valves using chainwheels.

K. Install valve tags. Comply with requirements in Section 230553 “Identification for HVAC Piping and Equipment” for valve tags and schedules.

Section 230529: Hangers and Supports for HVAC Piping and Equipment

Consultant shall provide a Section for this system that complies with all of the following requirements:

All equipment supports and thermal expansion compensation shall be manufactured systems or designed and detailed by a Colorado Registered Professional Engineer. Supports shall be coordinated with Architectural and Structural disciplines. Under no circumstances shall the construction documents direct a Contractor to provide supports without detailed performance specifications outlining criteria and requirements of supports and their design and installation.

Delegated design of hangers is not allowed at DEN. Remove all references to delegated design of hangers from Specifications.

The following hanger material types are not allowed at DEN. Remove all references the following hanger material types from Specifications: Copper, Aluminum, Fiberglass, and Plastic

Only MFMA Manufacturers are allowed for metal framing systems. Remove all references to non-MFMA Manufacturers' metal framing systems from Specifications.

The following hanger types are not allowed at DEN. Remove all references to the following hanger types from Specifications: Snubbers, Rigid-Type Restraints and Accessories, Cable-Type Restraints and Accessories, Post-Installed Concrete Anchors, and Concrete Inserts.

Powder-Actuated Fasteners are not allowed at DEN. Remove all references to Powder-Actuated Fasteners from Specifications.

PART 1 GENERAL

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 HANGER AND SUPPORT INSTALLATION

A. Insulated Piping:

1. Attach clamps and spacers to piping.
   a. Piping Operating above Ambient Air Temperature: Clamp may project through insulation.
   b. Piping Operating below Ambient Air Temperature: Use thermal-hanger shield insert with clamp sized to match OD of insert.
   c. Do not exceed pipe stress limits allowed by ASME B31.9 for building services piping.
2. Install MSS SP-58, Type 39, protection saddles if insulation without vapor barrier is indicated. Fill interior voids with insulation that matches adjoining insulation.
   a. Option: Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 and larger if pipe is installed on rollers.
3. Install MSS SP-58, Type 40, protective shields on cold piping with vapor barrier. Shields shall span an arc of 180 degrees.
   a. Option: Thermal-hanger shield inserts may be used. Include steel weight-distribution plate for pipe NPS 4 and larger if pipe is installed on rollers.
4. Shield Dimensions for Pipe: Not less than the following:
   a. NPS 1/4 to NPS 3-1/2: 12 inches) long and 0.048 inch thick.
   b. NPS 4: 12 inches long and 0.06 inch thick.
   c. NPS 5 and NPS 6: 18 inches long and 0.06 inch thick.
   d. NPS 8 to NPS 14: 24 inches long and 0.075 inch thick.
   e. NPS 16 to NPS 24: 24 inches long and 0.105 inch thick.

5. Pipes NPS 8 and Larger: Include wood or reinforced calcium-silicate-insulation inserts of length at least as long as protective shield.
6. Thermal-Hanger Shields: Install with insulation same thickness as piping insulation.

Section 230533: Heat Tracing for HVAC Piping

PART 1 GENERAL

1.01 GENERAL

A. Heat trace systems are not considered best practice and shall only be considered when no other option exists. Obtain written permission from DEN Mechanical Engineer.

B. If heat trace systems are allowed, then system to include controls with BACNet interface to EMCS for notification of failure in the system. Include integration into the EMCS for operational status and failure notification to maintenance Staff.

Heat trace as described in this DSM apply to both plumbing and HVAC piping.

1.02 WARRANTY

A. Coordinate warranty requirements with DEN Project Manager.

1. Special Warranty: Manufacturer agrees to repair or replace electric heating cable that fails in materials or workmanship within specified warranty period.

B. Verify available warranties and warranty periods for electric heating cable. Special warranties often exclude labor.

C. Warranty Period: Minimum three (3) years from date of Substantial Completion

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 INSTALLATION

A. Indicate location of controls on Drawings.

B. Install warning tape on piping insulation where piping is equipped with electric heating cables.

Section 230548.13: Vibration Controls for HVAC

PART 1 GENERAL

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 PIPE ISOLATION SCHEDULE

Provide schedules to indicate the combination of equipment base and vibration isolator required.

Pipe Size (in)	Isolated Distance from Equipment (Pipe Diameters)
1	120
2	90
3	80
4	75
6	60

8	60
10	54
12	50
16	45
24	38

3.02 EQUIPMENT ISOLATION SCHEDULE

Edit, delete, add to, and complete following schedule to suit isolation requirements for equipment actually used for Project.

Isolated Equipment	Base	Type	Static Deflection
Roof Mounted AHUs	Roof Curb	E	2"
Roof Mounted AHU, MAU Fans	Steel Frame	B	2"
Roof Mounted Fans, MAU's	Roof Curb	D	0.1"
Chillers	Concrete Pad	D	0.2" (provide 3/4" thick pads)
Cooling Towers	Roof Curb	D	0.1"
Piping	NA	C	0.5"

Section 230553: Identification for HVAC Piping and Equipment

PART 1 GENERAL

PART 2 PRODUCTS

2.01 CEILING TACKS

A. Include ceiling tacks if needed for locating valves, etc., above accessible ceilings. These shall not be used in lieu of required equipment tags.

B. Description: Steel with 3/4 inch diameter color coded head.

C. Color code ceiling tacks as follows:

1. Yellow: HVAC equipment.
2. Red: Fire dampers/smoke dampers.
3. Green: Plumbing valves.
4. Blue: Heating/cooling valves.

PART 3 EXECUTION

3.01 GENERAL INSTALLATION REQUIREMENTS

A. Equipment: Identify air handling units, pumps, heat transfer equipment, tanks, and water treatment devices with plastic nameplates or stencil painting. Small devices, such as in-line pumps, may be identified with metal tags. At a minimum, the nameplate shall contain the following information:

1. Equipment Tag.
2. Equipment location.
3. Service Area.
4. Flowrate (cfm/gpm).

5. Capacity (btuh/kw).

Item below shall be edited to reflect who owns and will maintain the equipment installed. For all tenant projects, this shall be edited to the name of the space (i.e., McDonald's). Item shall be deleted for all DEN systems.

6. <Equipment owner>

B. Below shall be used for all base building equipment. Tenant equipment above the ceiling with the exception of vav boxes connecting the base building system do not need to be identified.

1. Equipment and terminal devices above ceiling:
   a. Provide adhesive backed plastic nameplate on ceiling grid support directly below equipment identifying unit tag and temperature control node number.
      1. Example:
         a. VAV-01NODE 067.

C. Controls: Identify control panels and major control components outside panels with plastic nameplates. Key to control schematics.

3.02 PIPE LABEL INSTALLATION

A. Pipe Label Locations: Locate pipe labels where piping is exposed or above accessible ceilings in finished spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and plenums; and exterior exposed locations as follows:

1. Near each valve and control device.
2. Near each branch connection, excluding short takeoffs for fixtures and terminal units. Where flow pattern is not obvious, mark each pipe at branch.
3. Near penetrations and on both sides of through walls, floors, ceilings, and inaccessible enclosures.
4. At access doors, manholes, and similar access points that permit view of concealed piping.
5. Near major equipment items and other points of origination and termination.
6. Spaced at maximum intervals of 50 feet along each run. Reduce intervals to 25 feet in areas of congested piping and equipment.
7. On piping above removable acoustical ceilings. Omit intermediately spaced labels.

3.03 VALVE-TAG INSTALLATION

A. Identify all valves, including fire protection valves, in main and branch piping located inside the building. Use tags secured with brass 'S' hooks or brass chains.

B. Stamp tags with a unique prefix to identify system to which applied, followed by a number (Example: CHWS-1, CHWS-2, etc.). In general, prefix shall match system abbreviations used on drawings where applicable.

C. Provide a typewritten listing of valves (VALVE CHART AND SCHEDULE) including valve identification number, location, function, normal position, service, and area served. Mount list as specified and directed. Include additional copy in operation and maintenance manuals.

D. Show valve tag designations on the project record document drawings, including schematic flow diagrams where included with construction documents.

E. Contractor shall prepare and install where directed, in aluminum frames with clear plastic protective cover, a valve location diagram in the form of a series of flow diagrams with each automatic or manually actuated control or shut-off valve clearly identified in sequence with its individual valve tag number. Automatic control valves shall be tagged to match designations shown on the temperature control drawings, and the specified valve charts shall be installed adjacent to valve location diagrams.

Valve-Tag Application Schedule: Tag valves according to size, shape, and color scheme and with captions similar to those indicated in the following subparagraphs: Other valve-tag sizes and shapes may be available if required.

1. Valve-Tag Size and Shape:
   a. Chilled Water: 2 inches, round.
   b. Condenser Water: 2 inches, round.
   c. Refrigerant: 2 inches, round.
   d. Hot Water: 2 inches, round.

Gas: 2 inches, round. Tag colors, if used, should follow the color schemes defined by ASME A13.1.

2. Valve-Tag Colors:
   a. Toxic and Corrosive Fluids: Black letters on a safety-orange background.
   b. Flammable Fluids: Black letters on a safety-yellow background.
   c. Combustible Fluids: White letters on a safety-brown background.
   d. Potable and Other Water: White letters on a safety-green background.
   e. Compressed Air: White letters on a safety-blue background.
   f. Defined by User: White letters on a safety-purple background, black letters on a safety-white background, white letters on a safety-gray background, and white letters on a safety-black background.

3.04 VALVE CHART AND SCHEDULE

A. Provide valve chart and schedule in aluminum frame with clear plastic shield. Install at location as directed by DEN Project Manager. See example below:

TAG #	Location	Function	Normal Position	Service	Area Served
CHWS-1	TML_05_11W_064	Isolation	OPEN	AHU-11 CHWS Upper coil connection	TML-04-11A-AHU-11
CHWS-2	TML_05_11W_064	Isolation	OPEN	AHU-11 CHWS Lower coil connection	TML-04-11A-AHU-11
CHWR-1	TML_05_11W_064	Isolation	OPEN	AHU-11 CHWR Upper coil connection	TML-04-11A-AHU-11
CHWR-2	TML_05_11W_064	Isolation	OPEN	AHU-11 CHWR Lower coil connection	TML-04-11A-AHU-11
HWS-1	TML_05_11W_064	Isolation	OPEN	AHU-11 HWS Upper coil connection	TML-04-11A-AHU-11
HWS-2	TML_05_11W_064	Isolation	OPEN	AHU-11 HWS Lower coil connection	TML-04-11A-AHU-11
HWR-1	TML_05_11W_064	Isolation	OPEN	AHU-11 HWR Upper coil connection	TML-04-11A-AHU-11
HWR-2	TML_05_11W_064	Isolation	OPEN	AHU-11 HWR Lower coil connection	TML-04-11A-AHU-11

3.05 PIPING IDENTIFICATION SCHEDULE

A. Pipe identification and color coding for general-use piping systems shall be in accordance with the following schedule. For plumbing piping identification schedule, reference Section 220553 “Identification for Plumbing Piping and Equipment”:

Engineer to edit table to suit Project. Include only systems being used.

Classification	**Band Color**	**Stenciled Legend**
Chilled Water Supply	Green	Ch. Water Supp.
Chilled Water Return	Green	Ch. Water Ret.
Condenser Water Supply	Green	Cond. Water Supp.
Condenser Water Return	Green	Cond. Water Ret.
Natural Gas	Yellow	Nat. Gas
L.P. Gas	Yellow	L.P. Gas
Gas Vent	Yellow	Gas Vent
Hot Water Heating Supply	Yellow	H.W. Htg. Supp.
Hot Water Heating Return	Yellow	H.W. Htg. Ret.
Compressed Air	Blue	Comp. Air
Snow Melting Supply	Yellow	Snow Melt Supp.
Snow Melting Return	Yellow	Snow Melt Ret.
Blow Down	Yellow	Blow Dn.
Refrigerant Hot Gas	Green	Refr. Hot Gas
Refrigerant Liquid	Green	Refr. Liq.
Water Treatment	Green	Water Trtmt.
Humidifier	Green	Humidifier
Expansion Tank No.	Yellow	Exp. Tank. No.
Gasoline	Yellow	Gasoline
Gasoline Vent	Yellow	Gasoline Vent
Fuel Oil (heating)	Yellow	Fuel Oil Htg.
Fuel Oil (generator)	Yellow	Fuel Oil Gen.
Diesel Exhaust	Yellow	Engine Exh.
Refrigerant Relief	Yellow	Refr. Relief
Glycol Supply (PCA)	Green	Gly. Sup.
Glycol Return (PCA)	Green	Gly. Ret.

B. Paint exterior piping and duct systems to match wall colors.

C. For fuel piping systems, piping identification shall conform to the following schedule:

For aircraft fueling systems projects, edit the following API color coding's to suit requirements. For AVGAS, type 100LL is often the product used.

Fuel Type	Band Colors	Stenciled Legend
Jet A	Black/Black Band	Jet A
Jet A-1	Black/2 Black Bands	Jet A-1
JP-4 (Jet B)	Black/3 Yellow Bands	JP-4
Avgas 115	Red/Purple Band	Avgas 115
Avgas 100	Red/Green Band	Avgas 100
Avgas 100LL	Red/Blue Band	Avgas 100LL
Avgas 80	Red/Red Band	Avgas 80

Section 230593: Testing, Adjusting, and Balancing for HVAC

PART 1 GENERAL

1.01 PREINSTALLATION MEETINGS

Engineer to retain "TAB Conference" Paragraph below for projects located in the Terminal Complex or if HVAC work is complex enough to justify a conference.

A. TAB Conference: Conduct a TAB conference at Location and time as determined by DEN Project Manager after approval of the TAB strategies and procedures plan to develop a mutual understanding of the details. Provide a minimum of 14 days' advance notice to DEN Project Manager of scheduled meeting time and location, with meeting to convene minimum one (1) week prior to commencing work of this Section.

B. Attendance shall include representatives of all systems and equipment Installers having performed, or in the process of performing, project work subject to testing, balancing, and adjustment by the TAB firm.

C. Conference agenda shall include review of status of installation and completion of each system requiring testing balancing and adjusting, for the purpose of confirming that the schedule of work to be performed will be planned so as to ensure readiness of systems.

D. Minimum Agenda Items:

1. The Contract Documents examination report.
2. The TAB plan.
3. Needs for coordination and cooperation of trades and subcontractors.
4. Proposed procedures for documentation and communication flow.

1.02 ACTION SUBMITTALS

A. Submit name of adjusting and balancing agency for approval within 30 days after award of Contract to ensure that the TAB firm has met the requirements this section of the Specifications and is on the Project from the outset of construction.

B. All TAB submittals shall be electronically submitted in PDF format to the DEN Project Manager and directly to the DEN Mechanical Engineer.

C. Schedule:

1. Provide a detailed schedule that includes TAB activities. Schedule is to include each tagged piece of equipment and the TAB date. Schedule is to be coordinated with the overall construction schedule.
2. Provide a general TAB activities schedule integrated into the overall construction schedule and include as line items for categories of TAB activities (i.e., Pump balancing, AHU balancing, Exhaust Fan balancing, etc.).
3. Update both schedules as the overall construction activities progress.

D. Field Reports: Indicate deficiencies in systems that would prevent proper testing, adjusting, and balancing of systems and equipment to achieve specified performance.

E. Prior to commencing work, submit report forms or outlines indicating adjusting, balancing, and equipment data required.

F. Submit draft copies of report for review prior to final acceptance of Project. Provide final copies for DEN Project Manager and for inclusion in operating and maintenance manuals.

NOTE TO DESIGNER: This section is required whenever a PLB is added or modified. It is the responsibility of the designer to adequately convey the information below on the contract documents to ensure the testing is complete within the required timeframe.

G. PLB Pre-test Report: Submit pre-test report prior to demolition or modifications to of any portion of passenger loading bridges, fixed walkway, and any HVAC systems connected to gate areas.

H. Test Reports: Indicate data on AABC National Standards for Total System Balance forms, or forms prepared following ASHRAE 111, NEBB or TABB forms. When necessary, supplement with forms containing information indicated in Schedules.

I. Final Report: At least fifteen (15) days prior to Contractor's request for final inspection, submit in letter size, a single PDF file of the final test report on applicable reporting forms for review. Each individual final reporting form must bear the signature of the person who recorded data and that of the reporting organization. Identify instruments of all types that were used and last date of calibration of each.

J. A statement outlining all abnormal or notable conditions not covered in above data.

K. Proposed resolutions to equipment that is performing outside of the specified performance ranges.

1.03 INFORMATIONAL SUBMITTALS

A. Qualification Data: Within 30 days of Contractor's Notice to Proceed, submit documentation that the TAB specialist and this Project's TAB team members meet the qualifications specified in “Quality Assurance” Article.

B. Contract Documents Examination Report: Within 30 days of Contractor's Notice to Proceed, submit the Contract Documents review report as specified in Part 3.

C. Strategies and Procedures Plan: Within 30 days of Contractor's Notice to Proceed, submit TAB strategies and step-by-step procedures as specified in “Preparation” Article.

D. System Readiness Checklists: Within 30 days of Contractor's Notice to Proceed, submit system readiness checklists as specified in “Preparation” Article.

E. Examination Report: Submit a summary report of the examination review required in “Examination” Article.

F. Certified TAB reports.

1. Sample report forms.
2. Instrument calibration reports, to include the following:
   a. Instrument type and make.
   b. Serial number.
   c. Application.
   d. Dates of use.
   e. Dates of calibration.

1.04 CLOSEOUT SUBMITTALS

Verify requirements for as-built plans with DEN Project Manager.

A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 “Submittal Procedures”.

1. Record actual locations of flow measuring stations, balancing valves and rough setting.

1.05 QUALITY ASSURANCE

A. Sequence work to commence after completion of systems and schedule completion of work before Substantial Completion of Project.

B. Schedule and provide assistance in final adjustment and test of life safety, smoke evacuation, and/or smoke control system with Fire Authority.

C. TAB Specialists Qualifications: Certified by AABC, NEBB or TABB.

1. TAB Field Supervisor: Employee of the TAB specialist and certified by AABC, NEBB or TABB.
2. TAB Technician: Employee of the TAB specialist and certified by AABC, NEBB or TABB as a TAB technician.

D. Instrumentation Type, Quantity, Accuracy, and Calibration: Comply with requirements in ASHRAE 111, Section 4, "Instrumentation."

E. ASHRAE/IESNA Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6.7.2.3- "System Balancing."

1.06 COORDINATION

A. Coordinate the efforts of factory-authorized service representatives for systems and equipment, HVAC controls installers, and other mechanics to operate HVAC systems and equipment to support and assist TAB activities.

B. Notice: Notify the DEN Project Manager, DEN Mechanical Inspector, and DEN Mechanical Engineer in writing a minimum of 72 hours prior to testing of any equipment and/or systems. Include scheduled test dates and times.

C. Perform TAB after leakage and pressure tests on air and water distribution systems have been satisfactorily completed.

1.07 FIELD CONDITIONS

A. Full Owner Occupancy: Owner will occupy the site and existing building during entire TAB period. Cooperate with Owner during TAB operations to minimize conflicts with Owner's operations.

1.08 WARRANTY

When warranties are required, verify with DEN Project Manager that special warranties stated in this article are not less than remedies available to DEN under prevailing local laws. Coordinate with Division 01.

A. Warranty of all equipment described in this Section shall meet warranty requirements of Section 017835 "Warranties and Bonds" and Section 230400 "Basic HVAC Requirements".

Retain paragraph below if AABC standards are used.

B. National Project Performance Guarantee: Provide a guarantee on AABC's "National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems" forms stating that AABC will assist in completing requirements of the Contract Documents if TAB firm fails to comply with the Contract Documents. Duration of Guarantee shall be 365 days. Guarantee includes the following provisions:

Retain paragraph below if NEBB or SMACNA standards are used.

C. Special Guarantee: Provide a guarantee on NEBB forms stating that NEBB will assist in completing requirements of the Contract Documents if TAB firm fails to comply with the Contract Documents. Duration of Guarantee shall be 365 days. Guarantee shall include the following provisions:

Retain both subparagraphs below with either paragraph above.

1. The certified TAB firm has tested and balanced systems according to the Contract Documents.
2. Systems are balanced to optimum performance capabilities within design and installation limits.

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 TAB SPECIALISTS

Coordinate requirements with DEN Project Manager.

A. Subject to compliance with requirements, engage one of the following:
   1. Able Balance Corp.
   2. Griffith Engineering Service.
   3. Jedi Balancing, Inc.
   4. JPG Engineering, Inc.
   5. TAB Services, Inc.
   6. or approved equal.

3.02 EXAMINATION

A. Examine the Contract Documents to become familiar with Project requirements and to discover conditions in systems designs that may preclude proper TAB of systems and equipment.

B. Examine installed systems for balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers. Verify that locations of these balancing devices are applicable for intended purpose and are accessible.

C. Examine the approved submittals for HVAC systems and equipment.

D. Examine ceiling plenums and underfloor air plenums used for supply, return, or relief air to verify that they are properly separated from adjacent areas. Verify that penetrations in plenum walls are sealed and fire-stopped if required.

E. Examine equipment performance data including fan and pump curves.
   1. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.
   2. Calculate system-effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from the conditions used to rate equipment performance. To calculate system effects for air systems, use tables and charts found in AMCA 201, “Fans and Systems,” or in SMACNA's “HVAC Systems- Duct Design.” Compare results with the design data and installed conditions.

F. Examine system and equipment installations and verify that field quality control testing, cleaning, and adjusting specified in individual Sections have been performed.

G. Examine test reports specified in individual system and equipment Sections.

H. Examine HVAC equipment and verify that bearings are greased, belts are aligned and tight, filters are clean, and equipment with functioning controls is ready for operation.

I. Examine terminal units, such as variable-air-volume boxes, and verify that they are accessible and their controls are connected and functioning.

J. Examine strainers. Verify that startup screens have been replaced by permanent screens with indicated perforations. Provide photographic documentation in report.

K. Examine control valves for proper installation for their intended function of throttling, diverting, or mixing fluid flows.

L. Examine heat-transfer coils for correct piping connections and for clean and straight fins.

M. Examine system pumps to ensure absence of entrained air in the suction piping.

N. Examine operating safety interlocks and controls on HVAC equipment.

O. Ensure the Following Conditions:
   1. Systems are started and operating in a safe and normal condition.
   2. Temperature control systems are installed complete and operable.

3. Proper thermal overload protection is in place for electrical equipment.
4. Final filters are clean and in place. If required, install temporary media in addition to final filters.
5. Duct systems are clean of debris.
6. Fans are rotating correctly.
7. Fire, smoke, and volume dampers are in place and open.
8. Air coil fins are cleaned and combed.
9. Access doors are closed and duct end caps are in place.
10. Air outlets are installed and connected.
11. Duct system leakage is minimized.
12. Return air paths are not obstructed (i.e. walls to structure).
13. Hydronic systems are flushed, filled, and vented.
14. Pumps are rotating correctly.
15. Proper strainer baskets are clean and in place. Provide photographic documentation in report.
16. Service and balance valves are open.

P. Report deficiencies discovered before and during performance of TAB procedures. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values.

3.03 PREPARATION

A. Provide instruments required for testing, adjusting, and balancing operations. Make instruments available to DEN Project Manager to facilitate spot checks during testing.

B. Provide additional balancing devices as required.

C. Prepare a TAB plan that includes the following:

1. Equipment and systems to be tested.
2. Strategies and step-by-step procedures for balancing the systems.
3. Instrumentation to be used.
4. Sample forms with specific identification for all equipment.

D. Perform system-readiness checks of HVAC systems and equipment to verify system readiness for TAB work. Include, at a minimum, the following:

1. Airside:
   a. Verify that leakage and pressure tests on air distribution systems have been satisfactorily completed.
   b. Duct systems are complete with terminals installed.
   c. Volume, smoke, and fire dampers are open and functional.
   d. Clean filters are installed.
   e. Fans are operating, free of vibration, and rotating in correct direction.
   f. Variable-frequency controllers' startup is complete and safeties are verified.
   g. Automatic temperature-control systems are operational.
   h. Ceilings are installed.
   i. Windows and doors are installed.
   j. Suitable access to balancing devices and equipment is provided.
2. Hydronics:
   a. Verify leakage and pressure tests on water distribution systems have been satisfactorily completed.
   b. Piping is complete with terminals installed.

c. Water treatment is complete.
d. Systems are flushed, filled, and air purged.
e. Strainers are pulled and cleaned. Provide photographic documentation in report.
f. Control valves are functioning per the sequence of operation.
g. Shutoff and balance valves have been verified to be 100 percent open.
h. Pumps are started and proper rotation is verified.
i. Pump gage connections are installed directly at pump inlet and outlet flanges or in discharge and suction pipe prior to valves or strainers.
j. Variable-frequency controllers' startup is complete and safeties are verified.
k. Suitable access to balancing devices and equipment is provided.

3.04 PROGRESS REPORTING

A. Initial Construction-Phase Report: Based on examination of the Contract Documents as specified in “Examination” Article, prepare a report on the adequacy of design for systems balancing devices. Recommend changes and additions to systems balancing devices to facilitate proper performance measuring and balancing. Recommend changes and additions to HVAC systems and general construction to allow access for performance measuring and balancing devices.

B. Status Reports: Prepare biweekly progress reports to describe completed procedures, procedures in progress, and scheduled procedures. Include a list of deficiencies and problems found in systems being tested and balanced. Prepare a separate report for each system and each building floor for systems serving multiple floors.

3.05 SCHEDULES

Engineer to provide a schedule to clarify which equipment is to be tested, adjusted, and balanced; to indicate where sound and vibration measurements are required; and to define the report requirements.

3.06 FINAL REPORT

The following is required for T&B on modifications to existing systems and is required for all tenant modifications. Coil data is not required for exhaust systems.

A. Measurement of existing equipment data prior to new work start.

1. Date of test on original equipment
2. Equipment tag
3. Inlet static pressure (inches WC)
4. Outlet static pressure (inches WC)
5. Outlet airflow (CFM)
6. Coil entering air and water temperatures (F).
7. Coil leaving air and water temperatures (F).
8. Motor electrical data, HP, voltage, and amperage at test time.

B. Measurement of existing equipment data upon completion of new work.

1. Date of test on original equipment
2. Equipment tag
3. Inlet static pressure (inches WC)
4. Outlet static pressure (inches WC)
5. Outlet airflow (CFM)
6. Coil entering air and water temperatures (F).
7. Coil leaving air and water temperatures (F).

8. Motor electrical data, HP, voltage, and amperage at test time.

Sound measurement is required in all spaces containing mechanical equipment and paging systems. Edit below for appropriate NC values from section 1.1.6 Noise Criteria:

9. Sound Measurement: Record sound measurements on octave band and dBA test forms and on an NC or RC chart indicating the decibel level measured in each frequency band for both "background" and "HVAC system operating" readings. Record each tested location on a separate NC or RC chart. Record the following on the forms:

   a. Date and time of test. Record each tested location on its own NC curve.
   b. Sound meter manufacturer, model number, and serial number.
   c. Space location within the building including floor level and room number.
   d. Diagram or color photograph of the space showing the measurement location.
   e. Time weighting of measurements, either fast or slow.
   f. Description of the measured sound: steady, transient, or tonal.
   g. Description of predominant sound source.
   h. Record measured octave bands with all area HVAC equipment off and all area HVAC equipment on.
   i. Sound data curves for measured equipment and/or spaces with baseline [NC-35] [NC-40] [NC-45] curves for compliance.

3.07 INSPECTIONS

A. Initial Inspection:

1. After testing and balancing are complete, operate each system and randomly check measurements to verify that the system is operating according to the final test and balance readings documented in the Final Report.
2. Randomly check the following for each system:

Engineer to edit random checks to coincide with TAB tests specified.

   a. Measure airflow of at least 10% of air outlets.
   b. Measure water flow of at least 5% of terminals.
   c. Measure room temperature at each thermostat/temperature sensor. Compare the reading to the set point.
   d. Measure sound levels at two locations.
   e. Measure space pressure of at least 10% of locations.
   f. Verify that balancing devices are marked with final balance position.
   g. Note deviations to the Contract Documents in the Final Report.

B. Final Inspection:

1. After initial inspection is complete and evidence by random checks verifies that testing and balancing are complete and accurately documented in the final report, request that a final inspection be made by DEN Project Manager, DEN Mechanical Engineer or their designated representative(s).
2. TAB firm test and balance engineer shall conduct the inspection in the presence of DEN Project Manager, DEN Mechanical Engineer or their designated representative(s).
3. DEN Project Manager, DEN Mechanical Engineer or their designated representative(s) shall randomly select measurements documented in the final report to be rechecked. The rechecking shall be limited to either 10% of the total measurements recorded, or the extent of measurements that can be accomplished in a normal 8-hour business day.

4. If the rechecks yield measurements that differ from the measurements documented in the final report by more than the tolerances allowed, the measurements shall be noted as "FAILED."
5. If the number of "FAILED" measurements is greater than 10% of the total measurements checked during the final inspection, the testing and balancing shall be considered incomplete and shall be rejected.
6. TAB firm shall recheck all measurements and make adjustments. Revise the final report and balancing device settings to include all changes and resubmit the final report.
7. Request a second final inspection. If the second final inspection also fails, Owner shall contract the services of another TAB firm to complete the testing and balancing in accordance with the Contract Documents and deduct the cost of the services from the final payment.

3.08 ADDITIONAL TESTS

Engineer to edit below to suit Project. Coordinate requirements with DEN Project Manager.

A. Within 90 days of completing TAB, perform additional TAB to verify that balanced conditions are being maintained throughout and to correct unusual conditions.

B. Seasonal Periods: If initial TAB procedures were not performed during near-peak summer and winter conditions, perform additional TAB during near-peak summer and winter conditions.

Section 230713: Duct Insulation

PART 1 GENERAL

1.01 DELIVERY, STORAGE, AND HANDLING

Retain this article to require shipping container markings. Container marking is an option in ASTM standards; default condition does not include the marking in this article unless specified in the Contract.

A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.

B. Deliver, store, protect, and handle products under provisions of Section 230400 "Basic HVAC Requirements" and Division 01.

C. Deliver materials to site in original factory packaging, labeled with manufacturer's density, thickness, and "R" value.

D. Store insulation in original wrapping and protect from weather and construction traffic.

E. Protect insulation against dirt, water, chemical, and mechanical damage.

PART 2 PRODUCTS

All products that emit VOCs used in indoor applications shall have a VOC content of 50 g/L or less when calculated according to 40 CFR 59, Subpart D (EPA Method 24). Edit all sections to comply with this requirement.

PART 3 EXECUTION

3.01 GENERAL INSTALLATION REQUIREMENTS

A. Install materials in accordance with manufacturer's instructions and N.I.C.A standards.

B. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.

1. Provide insulation with vapor barrier when air conveyed may be below ambient temperature, and for all runs of heating duct which exceed 75 feet in maximum air-travel distance.

C. High Temperature Insulation Application: Secure insulation with wires and treat joints as recommended by the manufacturer.

D. Walk-in Plenum Application: Adhere insulation on interior surface of plenum with adhesive for 100 percent coverage. Secure insulation with weld pins and split washers, 12" center to center. Seal and smooth joints. Do not use nail- type fasteners.

3.02 PENETRATIONS

A. Where staples are used to secure insulation covering requiring vapor barrier, the staples shall be sealed with a vapor barrier mastic.

3.03 DUCT INSULATION SCHEDULE, GENERAL

A. Items Not Insulated:

1. Nameplates and data plates.

B. Access panels and doors in air-distribution systems

Section 230716: HVAC Equipment Insulation

PART 1 GENERAL

1.01 SUMMARY

A. Include insulating the following HVAC systems:

1. Condensate drain equipment, indoors when subject to condensation and outdoors.
2. Chilled-water and brine equipment, indoors and outdoors.
3. Condenser-water equipment, indoors when used for waterside economizer or for condensate control and outdoors.
4. Heating hot-water equipment, indoors and outdoors.
5. Steam and steam condensate equipment, indoors and outdoors.
6. Refrigerant equipment, indoors and outdoors.
7. Dual-service heating and cooling equipment, indoors and outdoors.
8. Heat-recovery equipment, indoors and outdoors.
9. Heated fuel-oil equipment, indoors and outdoors.

1.02 INFORMATIONAL SUBMITTALS

A. Installer Certificates: Signed by the Contractor certifying that installers comply with requirements.

PART 2 PRODUCTS

2.01 FIELD-APPLIED PVC JACKETS

A. Color: Color-code PVC jackets based on system. Color as verified by DEN Project Manager.

PART 3 EXECUTION

3.01 INSTALLATION OF FIELD-APPLIED JACKETS

A. For equipment exposed in mechanical equipment rooms or in finished spaces and conveying fluids below ambient temperature shall have vapor barrier jackets, factory-applied or field-applied. Insulate associated fittings, joints, and valves with molded insulation of like material and thickness as adjacent equipment, and finish with glass cloth and vapor barrier adhesive. PVC jackets may be used if in accordance with specified flame spread and smoke developed limitations insulate as for concealed applications. Finish with PVC jackets color-coded to match system – colors below are DEN standard but need to be verified with Project Manager:

1. Chilled Water – Dark Blue
2. Heating Water – Red
3. Dual-service heating and cooling- White
4. Domestic Cold Water – PVC Jacket not required but jacketing is to be painted Green
5. Domestic Hot Water – PVC Jacket not required but jacketing is to be painted Red
6. Domestic Recirculating Water – PVC Jacket not required but jacketing is to be painted Red.
7. Non-Potable Water- PVC Jacket not required but jacketing is to be painted Purple
8. Blowdown Drain – Should match the heating or chilled water system it is a part of and be clearly labeled as a Blowdown Drain
9. Hot Water Relief Piping – Yellow
10. Vent Piping from blowdown separator – Red but clearly labeled as vent piping.

B. Exterior Applications: Provide vapor barrier jackets. Cover with aluminum jacket with seams located on bottom side of horizontal equipment. Insulate associated fittings, joints, and valves with insulation of like material and thickness as adjoining pipe, and finish with glass mesh reinforced vapor barrier cement.

3.02 INSTALLATION OF EQUIPMENT, TANK, AND VESSEL INFORMATION

A. Insulation Installation on Pumps:

1. Fabricate metal boxes lined with insulation. Fit boxes around pumps and coincide box joints with splits in pump casings. Fabricate joints with outward bolted flanges. Secure the box sections together using a field-adjustable latching mechanism.
2. Fabricate boxes from galvanized steel, aluminum or stainless steel, at least 0.050 inch thick.
3. For below-ambient services, install a vapor barrier at seams, joints, and penetrations. Seal between flanges with replaceable gasket material to form a vapor barrier.

3.03 FINISHES

A. Color: Final paint color as selected by DEN Project Manager. Vary first and second coats to allow visual inspection of the completed Work.

Section 230719: HVAC Piping Insulation

PART 1 GENERAL

1.01 SUMMARY

A. Include insulating the following HVAC piping systems:

1. Condensate drain piping, indoors when subject to condensation and outdoors.
2. Chilled-water and brine piping, indoors and outdoors.
3. Condenser-water piping, indoors when used for waterside economizer or for condensate control and outdoors.
4. Heating hot-water piping, indoors and outdoors.
5. Steam and steam condensate piping, indoors and outdoors.
6. Refrigerant suction and hot-gas piping, indoors and outdoors.
7. Dual-service heating and cooling piping, indoors and outdoors.
8. Heat-recovery piping, indoors and outdoors.
9. Heated fuel-oil piping, indoors and outdoors.

1.02 INFORMATIONAL SUBMITTALS

A. Installer Certificates: Signed by the Contractor certifying that installers comply with requirements.

PART 2 PRODUCTS

2.01 FIELD-APPLIED JACKETS

A. Color: Color-code PVC jackets based on system. Color as verified by DEN Project Manager.

PART 3 EXECUTION

3.01 GENERAL PIPE INSULATION INSTALLATION

A. Insulation Installation on Unions:

1. Stencil or label the outside insulation jacket of each union with the word "union." Match size and color of pipe labels.

3.02 INSTALLATION OF FIELD-APPLIED JACKETS

A. Indoor, Concealed Applications: Insulated pipes conveying fluids above ambient temperature shall have standard jackets, with vapor barrier, factory-applied or field-applied. Insulate fittings, joints, and valves with insulation of like material and thickness as adjoining pipe, and finish with glass cloth and adhesive. PVC jackets may be used if in accordance with specified flame spread and smoke developed limitations.

B. Indoor, Concealed Applications: Insulated dual-temperature pipes or pipes conveying fluids below ambient temperature shall have vapor barrier jackets, factory-applied or field-applied. Insulate fittings, joints, and valves with molded insulation of like material and thickness as adjacent pipe, and finish with glass cloth and vapor barrier adhesive.

C. Indoor, Exposed Applications: For pipe exposed in mechanical equipment rooms or in finished spaces, insulate as for concealed applications. Finish with PVC jackets color-coded to match system – colors below are DEN standard but need to be verified with Project Manager:

1. Chilled Water – Dark Blue
2. Heating Water – Red
3. Dual-service heating and cooling – White
4. Domestic Cold Water – PVC Jacket not required but is to be painted Green
5. Domestic Hot Water – PVC Jacket not required but is to be painted Red
6. Domestic Recirculating Water – PVC Jacket not required but is to be painted Red
7. Non-Potable Water- PVC Jacket not required but factory applied jacketing Blowdown Drain – Should match the heating or chilled water system it is a part of and be clearly labeled as a Blowdown Drain
8. Hot Water Relief Piping – Yellow
9. Vent Piping from blowdown separator – Red but clearly labeled as vent piping.

D. Exterior Applications: Provide vapor barrier jackets. Cover with aluminum jacket with seams located on bottom side of horizontal piping. Insulate fittings, joints, and valves with insulation of like material and thickness as adjoining pipe, and finish with glass mesh reinforced vapor barrier cement.

E. Buried Piping: Provide factory fabricated assembly with inner all-purpose service jacket with self-sealing lap, and asphalt impregnated open mesh glass fabric, with one mil thick aluminum foil sandwiched between three layers of bituminous compound; outer surface faced with a polyester film.

3.03 FINISHES

A. Color: Final paint color as selected by DEN Project Manager. Vary first and second coats to allow visual inspection of the completed Work if painting is required.

3.04 FIELD QUALITY CONTROL

A. Inspect pipe, fittings, strainers, and valves, randomly selected by DEN Project Manager, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to three locations of straight pipe, three locations of threaded fittings, three locations of welded fittings, two locations of threaded strainers, two locations of welded strainers, three locations of threaded valves, and three locations of flanged valves for each pipe service defined in the “Piping Insulation Schedule, General”, “Indoor Piping Insulation Schedule”, and “Outdoor, Aboveground Piping Insulation Schedule” Articles.

Section 230800: Commissioning of HVAC

PART 1 GENERAL

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 DEMONSTRATION TEST

A. After completion of system start-up, operating performance test and commissioning, but before Owner acceptance, the Contractor shall conduct a 72-hour dynamic mode demonstration of the systems provided under this Contract. The intent of the 72-hour dynamic test is to verify that the mechanical and electrical equipment will respond as designed to meet the changes that may occur under varying indoor/outdoor conditions including seasonal variations and occupancy loads.

Engineer to create a detailed procedure and sequence of events for the contractor.

B. Procedures and sequence of events should contain as a minimum the following activities:

1. Hours 1-4: Bring all systems online for standard operations and parameters.
2. Hours 5-28: Operate all systems under normal parameters and verify proper operation.
3. Hours 29-68: Validation of systems operation through indoor/outdoor changes to include heating, cooling, ventilation, humidity control, domestic and control systems.
4. Hours 69-72: Return of systems to normal operation.

C. Systems and their associated equipment which are to be included in the dynamic test are all systems and components furnished under this Contract and as a minimum will include, but are not limited to the following:

1. Pressurization Air Handling Systems.
2. Air Handling Systems.
3. Chilled Water Systems.
4. Domestic Water Systems.
5. Fan Coil Systems.
6. Pumping Systems.
7. Exhaust Systems.
8. Air Filtration Systems.
9. Building Management and Control Systems.

D. Contractor shall notify the Owner and CxA in writing that the Project is completed and ready for the demonstration test. Schedule for test will then be established and documented. Initiation of the 72-hours dynamic test will not occur until all systems are balanced, operational, and incorporated into the building management and control system. Should the demonstration test fail for any reason, the problems shall be corrected, and another demonstration test conducted. Should the first or one subsequent demonstration test fail, the Owner reserves the right to obtain compensation from the Contractor for fees and expenses incurred in conjunction with having to witness more than two (2) 72-hour demonstration tests.

E. The attendees of each 72-hour demonstration test shall include representative from the following organizations:

1. General Contractor.
2. Mechanical Contractor.
3. Electrical Contractor.
4. Test and Balance Contractor.
5. Building Management and Control System Contractor.
6. DEN Project Manager of Record.
7. Mechanical Engineer.
8. Electrical Engineer.
9. Commissioning Agent.

F. Minor problems are anticipated, and the necessary personnel required to correct problems and adjust systems need to be available to insure continuation of the dynamic testing process. If major problems are encountered, at the discretion of the Owner and CxA, the testing will be terminated and rescheduled.

G. The Contractor shall notify any external organizations, which would include but not be limited to, Fire Department which are not directly involved in the testing but might be affected due to interface to ensure that alarms do not occur.

H. During the demonstration test, all systems shall operate in the "hands-off" automatic mode in accordance with the requirements of the Contract Documents. Changes in operating modes required to simulate load shifting, seasonal changeover, emergency modes, etc., will be accomplished by changing set points and equipment operating status at the BMS central control console as required to observe capacity control and monitoring. Provide a readout of space temperature at each thermostat building relative humidity, building pressurization, chilled water supply and return temperatures and chiller capacity.

Section 230923: Direct Digital Control (DDC) System for HVAC

PART 1 GENERAL

Note: Coordinate specifications with the requirements and information contained in the Controls Chapter 5 of this DSM as well as Chapter 13 of the Communications & Electronic Systems DSM.

Note: Tenant Water and BTU Meters to be on IE Dedicated Engine. See Communications and Electronic Systems DSM for more networking requirements.

1.01 ACTION SUBMITTALS

A. Product Data: For each type of product include the following:

1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
2. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
3. Product description with complete technical data, performance curves, and product specification sheets.

4. Installation, operation, and maintenance instructions including factors effecting performance.
5. Bill of materials of indicating quantity, manufacturer, and extended model number for each unique product.
    a. Gateways.
    b. Routers.
    c. Protocol analyzers.
    d. DDC controllers.
    e. Enclosures.
    f. Electrical power devices.
    g. UPS units.
    h. Accessories.
    i. Instruments.
    j. Control dampers and actuators.
    k. Control valves and actuators.
6. When manufacturer's product datasheets apply to a product series rather than a specific product model, clearly indicate and highlight only applicable information.
7. Each submitted piece of product literature shall clearly cross reference specification and drawings that submittal is to cover.

B. Shop Drawings:

Reference Section 230400 for additional submittal requirements.

1. General Requirements:
    a. Include cover drawing with Project name, location, Owner, Architect, Contractor, and issue date with each Shop Drawings submission.
    b. Include a drawing index sheet listing each drawing number and title that matches information in each title block.
2. Include plans, elevations, sections, and mounting details where applicable.
3. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
4. Detail means of vibration isolation and show attachments to rotating equipment.
5. Plan Drawings indicating the following:
    a. Screened backgrounds of walls, structural grid lines, HVAC equipment, ductwork, and piping.
    b. Room names and numbers with coordinated placement to avoid interference with control products indicated.
    c. Each desktop operator workstation, server, gateway, router, DDC controller, control panel instrument connecting to DDC controller, and damper and valve connecting to DDC controller, if included in Project.
    d. Exact placement of products in rooms, ducts, and piping to reflect proposed installed condition.
    e. Network communication cable and raceway routing.
    f. Information, drawn to scale, of contract drawings.
    g. Proposed routing of wiring, cabling, conduit, and tubing, coordinated with building services for review before installation.
6. Schematic drawings for each controlled HVAC system indicating the following:

a. I/O points labeled with point names shown. Indicate instrument range, normal operating set points, and alarm set points. Indicate fail position of each damper and valve, if included in Project.

b. I/O listed in table format showing point name, type of device, manufacturer, model number, and cross-reference to product data sheet number.

c. A graphic showing location of control I/O in proper relationship to HVAC system.

d. Wiring diagram with each I/O point having a unique identification and indicating labels for all wiring terminals.

e. Unique identification of each I/O that shall be consistently used between different drawings showing same point.

f. Elementary wiring diagrams of controls for HVAC equipment motor circuits including interlocks, switches, relays, and interface to DDC controllers.

g. Narrative sequence of operation.

h. Graphic sequence of operation, showing all inputs and output logical blocks.

7. Control panel drawings indicating the following:

a. Panel dimensions, materials, size, and location of field cable, raceways, and tubing connections.

b. Interior subpanel layout, drawn to scale and showing all internal components, cabling and wiring raceways, nameplates and allocated spare space.

c. Front, rear, and side elevations and nameplate legend.

d. Unique drawing for each panel.

8. DDC system network riser diagram indicating the following:

a. Each device connected to network with unique identification for each.

b. Interconnection of each different network in DDC system.

c. For each network, indicate communication protocol, speed, and physical means of interconnecting network devices, such as copper cable type, or fiber-optic cable type. Indicate raceway type and size for each.

d. Each network port for connection of an operator workstation or other type of operator interface with unique identification for each.

9. DDC system electrical power riser diagram indicating the following:

a. Each point of connection to field power with requirements (volts/phase//hertz/amperes/connection type) listed for each.

b. Each control power supply including, as applicable, transformers, power-line conditioners, transient voltage suppression and high filter noise units, DC power supplies, and UPS units with unique identification for each.

c. Each product requiring power with requirements (volts/phase//hertz/amperes/connection type) listed for each.

d. Power wiring type and size, race type, and size for each.

10. Monitoring and control signal diagrams indicating the following:

a. Control signal cable and wiring between controllers and I/O.

b. Point-to-point schematic wiring diagrams for each product.

11. Color graphics indicating the following:

a. Itemized list of color graphic displays to be provided.

b. For each display screen to be provided, a true color copy showing layout of pictures, graphics and data displayed.

c. Intended operator access between related hierarchical display screens.

C. System Description:

1. Full description of DDC system architecture, network configuration, operator interfaces and peripherals, servers, controller types and applications, gateways, routers and other network devices, and power supplies.
2. Complete listing and description of each report, log and trend for format and timing and events which initiate generation.
3. System and product operation under each potential failure condition including, but not limited to, the following:
   a. Loss of power.
   b. Loss of network communication signal.
   c. Loss of controller signals to inputs and outpoints.
   d. Server failure.
   e. Gateway failure.
   f. Network failure
   g. Controller failure.
   h. Instrument failure.
   i. Control damper and valve actuator failure.
4. Complete bibliography of documentation and media to be delivered to Owner.
5. Description of testing plans and procedures.
6. Description of Owner training.

D. Delegated-Design Submittal: For DDC system products and installation indicated as being delegated.

1. Supporting documentation showing DDC system design complies with performance requirements indicated, including calculations and other documentation necessary to prove compliance.

1.02 INFORMATIONAL SUBMITTALS

A. Coordination Drawings:

1. Plan drawings and corresponding product installation details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
   a. Product installation location shown in relationship to room, duct, pipe, and equipment.
   b. Structural members to which products will be attached.
   c. Wall-mounted instruments located in finished space showing relationship to light switches, fire-alarm devices, and other installed devices.
   d. Size and location of wall access panels for products installed behind walls and requiring access.
2. Reflected ceiling plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
   a. Ceiling components.
   b. Size and location of access panels for products installed above inaccessible ceiling assemblies and requiring access.
   c. Items penetrating finished ceiling including the following:
      1. Lighting fixtures.
      2. Air outlets and inlets.
      3. Speakers.
      4. Sprinklers.
      5. Access panels.
      6. Motion sensors.

7. Pressure sensors.
8. Temperature sensors and other DDC control system instruments.

Verify requirements for maintenance materials with DEN Project Manager.

1.03 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish quantity indicated of matching product(s) in Project inventory for each unique size and type of following:

1. Network Controller: One.
2. Programmable Application Controller: One.
3. Application-Specific Controller: One.
4. Carbon Dioxide Sensor and Transmitter: One.
5. Moisture Sensor and Transmitter: One.
6. Pressure Sensor and Transmitter: One.
7. Temperature Sensor and Transmitter: One.
8. General-Purpose Relay: One.
9. Multifunction Time-Delay Relay: One.
10. Latching Relay: One.
11. Current-Sensing Relay: One.
12. Combination On-Off Status Sensor and On-Off Relay: One.
13. Transformer: One.
14. DC Power Supply: One.
15. Supply of 20 percent spare fiber-optic cable splice organizer cabinets for several re-terminations.
16. Software for DEN operators to modify and create their own graphics for the controls system software, and modify and create their own Sequences of Operations for the HVAC controls.

1.04 WARRANTY

A. Manufacturer's Warranty: Manufacturer and Installer agree to repair or replace products that fail in materials or workmanship within specified warranty period.

1. Failures shall be adjusted, repaired, or replaced at no additional cost or reduction in service to Owner.
2. Include updates or upgrades to software and firmware if necessary to resolve deficiencies.
   a. Install updates only after receiving Owner's written authorization.
3. Warranty service shall occur during normal business hours and commence within 24 hours of Owner's warranty service request.
4. Warranty Period: Two years from date of Substantial Completion.
   a. For Gateway: Two-year parts and labor warranty for each.

PART 2 PRODUCTS

2.01 MANUFACTURERS

Remove Honeywell as an accepted manufacturer.

A. Subject to compliance with requirements, provide products by one of the following:

1. Johnson Controls, Inc
2. Automated Logic Corporation
3. Alerton

Work associated with equipment in the Central Plant (CUP), Concourse Pump Rooms, Terminal Pump Room, and the AOB pump room is to be Johnson Controls, Inc. for direct integration into the EMCS system. Remove any existing Honeywell and Automated Logic Corporation controls for existing equipment to remain and replace with Johnson Controls and integrate into the EMCS. Update the existing equipment's Sequence of Operation as needed for control replacement.

2.02 PERFORMANCE REQUIREMENTS

A. Future Expandability:

1. DDC system size shall be expandable to an ultimate capacity of at least two times total I/O points indicated.
2. Additional DDC controllers, I/O and associated wiring shall be all that is needed to achieve ultimate capacity. Initial network infrastructure shall be designed and installed to support ultimate capacity.
3. Operator interfaces installed initially shall not require hardware and software additions and revisions for ultimate capacity.

B. Network Bandwidth: Design each network of DDC system to include at least 30 percent available spare bandwidth with DDC system operating under normal and heavy load conditions. Calculate bandwidth usage and apply a safety factor to ensure that requirement is satisfied when subjected to testing under worst case conditions.

C. Backup Power Source:

1. HVAC systems and equipment served by an emergency/life safety backup power source shall have associated DDC system products that control such systems and equipment also served from the same backup power source.

D. UPS:

Refer to Section 263353 for UPS product requirements.

1. Provide sixty (60) minute UPS backup for the following DDC system products:
   a. Gateways.
   b. Routers
   c. DDC controllers.
   d. Network Devices
2. Provide sixty (60) minute UPS backup for the following DDC system instruments:
   a. Chilled Water
   b. Heating Water
   c. Condenser Water
   d. Natural Gas
   e. Fuel Oil
   f. Compressed Air
   g. Dual-Temperature Heating and Cooling Water
3. UPS shall include dry contacts or digital output points for low battery-on (primary utility power failure) conditions. Connect the points on the EMCS system to generate alarm(s) to be sent to the operator. Include on the graphics screen for the equipment served from each UPS status of these alarms.

E. Continuity of Operation after Electric Power Interruption:

1. Equipment and associated factory-installed controls, field-installed controls, electrical equipment, and power supply connected to building normal and backup power systems shall automatically return equipment and associated controls to operating state occurring

immediately before loss of normal power, without need for manual intervention by operator when power is restored either through backup power source or through normal power if restored before backup power is brought online.

2.03 SYSTEM ARCHITECTURE

A. DDC system shall consist of dedicated LANs that are controlled and monitored by DEN Business Technologies.

2.04 DDC SYSTEM OPERATOR INTERFACES

A. Operator Means of System Access: Operator shall access DDC system through DEN established control and security.

1. Day-to-day operation: via and DEN configured workstation with access to the system. These are specific machines at DEN and should be coordinated as required
2. For new work: desktop or portable operator workstation only during construction from a controlled and secured contractor location. This point of access is to be removed after work is completed.
3. Remote access: VIA a controlled and monitored Virtual server as determined by business needs.

B. Network Ports: For hardwired connection of desktop or portable operator workstation. Network port shall be properly protected, clearly labeled, and installed at the following locations:

1. Security system command center.
2. Fire-alarm system command center.

C. Desktop Workstations:

1. Provided, configured, and controlled by DEN.

D. Portable Workstations:

1. Allowed on a case-by-case basis contracted work.
2. For DEN Maintenance staff only, Provided, configured, and controlled by DEN as needed. No other portable devices are allowed.

E. Critical Alarm Reporting:

1. Operator-selected critical alarms shall be sent by DDC system to notify operator of critical alarms that require immediate attention.
2. DDC system shall send alarm notification to multiple recipients that are assigned for each alarm.
3. DDC system shall notify recipients by e-mail

2.05 NETWORKS

A. Acceptable networks for connecting programmable application controllers include the following:

1. ASHRAE 135-2012 (BAcnet MS/TP)

B. Acceptable networks for connecting application-specific controllers include the following:

1. ASHRAE 135-2012 (BAcnet MS/TP)

2.06 NETWORK COMMUNICATION PROTOCOL

A. Network communication protocol(s) used throughout entire DDC system shall be open to public and available to other companies for use in making future modifications to DDC system.

B. ASHRAE 135 Protocol:

1. ASHRAE 135 communication protocol shall be sole and native protocol used throughout entire DDC system.
2. DDC system shall not require use of gateways except to integrate HVAC equipment and other building systems and equipment, not required to use ASHRAE 135 communication protocol.
3. If used, gateways shall connect to DDC system using ASHRAE 135 communication protocol and Project object properties and read/write services indicated by interoperability schedule.
4. Operator workstations, controllers, and other network devices shall be tested and listed by BACnet Testing Laboratories.

C. Industry Standard Protocols:

1. DDC system networks using ASHRAE 135 communication protocol shall be an open implementation of network devices complying with ASHRAE 135. Network devices shall be tested and listed by BACnet Testing Laboratories.
   a. Portions of DDC system networks using Modbus Application Protocol Specification V1.1b communication protocol shall be an open implementation of network devices and technology complying with Modbus Application Protocol Specification V1.1b.
   b. BACnet Gateways shall be used to connect any non-BACnet networks to the DEN EMCS.

2.07 PORTABLE OPERATOR WORKSTATIONS (LAPTOP)

A. Laptops shall be DEN Business Technologies provided standard laptops. Any manufacturer-required software for the maintenance and support of system devices shall be installed with the assistance of the DEN Business Technologies group and the specific manufacturer/software provider.

2.08 SERVERS

A. DEN EMCS servers are virtual servers provided, configured, and backed up with coordination from the DEN EMCS Administrator and the DEN Business Technologies group.

2.09 SYSTEM SOFTWARE

A. Operator Interface Software:

1. Security Access:
   a. Operator access to DDC system shall be controlled and integrated with the DEN Active Directory.

B. Project-Specific Graphics: Graphics documentation including, but not limited to, the following:

1. Site plan showing each building, and additional site elements, which are being controlled or monitored by DDC system.
2. Plan for each building floor, including interstitial floors, and each roof level of each building, showing the following:
   a. Room layouts with room identification and name.
   b. Locations and identification of all monitored and controlled HVAC equipment and other equipment being monitored and controlled by DDC system.
   c. Location and identification of each hardware point being controlled or monitored by DDC system.
3. Control schematic for each of following, including a graphic system schematic representation, similar to that indicated on Drawings, with point identification, set point and dynamic value indication, and sequence of operation.
4. Graphic display for each piece of equipment connected to DDC system through a data communications link. Include dynamic indication of all points associated with equipment.
5. DDC system network riser diagram that shows schematic layout for entire system including all networks and all controllers, gateways and other network devices.

6. Graphic displays shall be built using standard templates for similar pieces of equipment

2.10 DDC CONTROLLERS

A. DDC Controller Spare Processing Capacity:

1. Include spare processing memory for each controller. RAM, PROM, or EEPROM will implement requirements indicated with the following spare memory:
   a. Network Controllers: 70 percent.
   b. Programmable Application Controllers: Not less than 70 percent.
   c. Application-Specific Controllers: Not less than 80 percent.
2. Memory shall support DDC controller's operating system and database and shall include the following:
   a. Monitoring and control.
   b. Energy management, operation, and optimization applications.
   c. Alarm management.
   d. Historical trend data of all connected I/O points.
   e. Maintenance applications.
   f. Operator interfaces.
   g. Monitoring of manual overrides.

B. DDC Controller Spare I/O Point Capacity: Include spare I/O point capacity for each controller as follows:

1. Network Controllers:
   a. 20 percent of each AI, AO, BI, and BO point connected to controller.
   b. Minimum Spare I/O Points per Controller:
      1. AIs: Three.
      2. AOs: Three.
      3. BIs: Five.
      4. BOs: Five.
2. Programmable Application Controllers:
   a. 20 percent of each AI, AO, BI, and BO point connected to controller.
   b. Minimum Spare I/O Points per Controller:
      1. AIs: Three.
      2. AOs: Three.
      3. BIs: Five.
      4. BOs: Five.
3. Application-Specific Controllers:
   a. 10 percent of each AI, AO, BI, and BO point connected to controller.
   b. Minimum Spare I/O Points per Controller:
      1. AIs: Two.
      2. AOs: Two.
      3. BIs: Two.
      4. BOs: Two.

2.11 UNINTERRUPTABLE POWER SUPPLY (UPS) UNITS

A. Refer to Section 263353 for UPS unit requirements.

B. Load served shall not exceed 75 percent of UPS rated capacity, including power factor of connected loads.

1. Larger-capacity units shall be provided for systems with larger connected loads.
2. UPS shall provide sixty (60) minutes of battery power.

C. Include tower models installed in ventilated cabinets or rack models installed on matching racks, as applicable to the particular installation location and space availability/configuration.

2.12 CONTROL WIRE AND CABLE

Engineer to coordinate requirements with Electrical DSM

2.13 CONTROL POWER WIRING AND RACEWAYS

Engineer to coordinate requirements with Electrical DSM

2.14 IDENTIFICATION

Engineer to coordinate this section with naming conventions listed in the DSM.

A. Control Equipment, Instruments, and Control Devices:

1. Engraved tag bearing unique identification.
    a. Include instruments with unique identification identified by equipment being controlled or monitored, followed by point identification.

PART 3 EXECUTION

3.01 DDC SYSTEM INTERFACE WITH EXISTING SYSTEMS

A. Interface with Existing Systems:

1. DDC systems shall interface existing systems to achieve integration.
2. Monitoring and Control of DDC System by Existing Control System:
    a. DDC system performance requirements shall be satisfied when monitoring and controlling DDC system by existing control system.
    b. Operator of existing system shall be able to upload, download, monitor, trend, control, and program every input and output point in DDC system from existing control system using existing control system software and operator workstations.
    c. Remote monitoring and control from existing control system shall not require operators of existing control system to learn new software.
    d. Interface of DDC system into existing control system shall be transparent to operators of existing control system and allow operators to monitor and control DDC system from any operator workstation connected to existing control system.
3. Integration of Existing Control System into DDC System:
    a. Existing control system performance requirements shall be satisfied when monitoring and controlling existing control system through DDC system.
    b. Operator shall be able to upload, download, monitor, alarm, report, trend, control, and program every input and output point in existing system from DDC system using operator workstations and software provided. The combined systems shall share one database.
    c. Interface of existing control system I/O points into DDC system shall be transparent to operators. All operational capabilities shall be identical regardless of whether I/O already exists or I/O is being installed.

B. Integration with Existing Enterprise System:

1. DDC system shall interface with an existing enterprise system to adhere to Owner standards already in-place and to achieve integration.

2. Engage Owner's control system integrator to provide the following services:
   a. Enterprise system expansion and development of graphics, logs, reports, trends and other operational capabilities of enterprise system for I/O being added to DDC control system for use by enterprise system operators.
   b. Limited assistance during commissioning to extent of DDC system integration with existing enterprise system.
   c. Prepare on-site demonstration mockup of integration of DDC system to be installed with existing system before installing DDC system.

3.02 IDENTIFICATION

Engineer to coordinate requirements with Electrical DSM

A. Identify system components, wiring, cabling, and terminals.

B. Install engraved phenolic nameplate with unique identification on face for each of the following:

1. Gateway.
2. Router.
3. Protocol analyzer.
4. DDC controller.
5. Enclosure.
6. Electrical power device.
7. UPS unit.
8. Accessory.

C. Install engraved phenolic nameplate with unique instrument identification on face of each instrument connected to a DDC controller.

D. Install engraved phenolic nameplate with identification on face of each control damper and valve actuator connected to a DDC controller.

E. Where product is installed above accessible tile ceiling, also install matching engraved phenolic nameplate with identification on face of ceiling grid located directly below.

F. Where product is installed above an inaccessible ceiling, also install engraved phenolic nameplate with identification on face of access door directly below.

G. Warning Labels:

1. Shall be permanently attached to equipment that can be automatically started by DDC control system.
2. Shall be located in highly visible location near power service entry points.

3.03 CONTROL WIRE, CABLE, AND RACEWAYS INSTALLATION

Engineer to coordinate requirements with Electrical DSM

Section 230923.11: Control Valves

PART 1 GENERAL

Delegated design of Control Valves is not allowed at DEN. Remove all references to delegated design of Control Valves in Specifications.

PART 2 PRODUCTS

Because the hydronic pumps at DEN are controlled by differential pressure transmitters, Three-Way Control Valves are not allowed at DEN. Remove all references to Three-Way Control Valves from Specifications.

Only pressure independent control valves are to be used. See section 6.1.5

Remove Honeywell as an accepted manufacturer.

PART 3 EXECUTION

Section 230923.12: Control Dampers

PART 1 GENERAL

Delegated design of Control Dampers is not allowed at DEN. Remove all references to delegated design of Control Dampers in Specifications.

PART 2 PRODUCTS

Remove Honeywell as an accepted manufacturer.

2.01 RECTANGULAR CONTROL DAMPERS

A. General Requirements

1. Damper Leakage: Comply with requirements in AMCA 500-D. Leakage shall not exceed 6.5 cfm per sq. ft. at a static-pressure differential of 4.0 inches water column when a torque of 5 inch pounds per sq. ft. is applied to the damper jackshaft.
2. Damper Rating: Rated for close-off pressure equal to the fan shutoff pressure.

2.02 GENERAL CONTROL-DAMPER ACTUATOR REQUIREMENTS

A. Operator Type: Direct coupled, designed for minimum 60,000 full-stroke cycles at rated torque.

Damper stroke time shall be no more than 90 seconds per 90 degree stroke.

PART 3 EXECUTION

Section 230923.14: Flow Instruments

PART 1 GENERAL

Delegated design of Flow Instruments is not allowed at DEN. Remove all references to delegated design of Flow Instruments in Specifications.

PART 2 PRODUCTS

Impeller-type flow meters are not allowed at DEN. Remove impeller-type flow meters from specifications.

PART 3 EXECUTION

Flow meter remote displays are to be located no higher than 6’-0” AFF.

Section 230923.17: Level Instruments

PART 1 PRODUCTS

DEN requires secondary drain pans to be used instead of Drain Pan Leak-Detection Switches, except with written permission from DEN Mechanical Engineer. Remove Drain Pan Leak Detection Switches from Specifications.

PART 2 PRODUCTS

Remove Honeywell as an accepted manufacturer.

PART 3 EXECUTION

Level instrument remote displays are to be located no higher than 6'-0" AFF.

Section 231113: Facility Fuel-Oil Piping

PART 1 GENERAL

Delegated design of Fuel-Oil Piping is not allowed at DEN. Remove all references to delegated design of Fuel-Oil Piping in Specifications.

1.01 FIELD CONDITIONS

A. Interruption of Existing Fuel-Oil Service: Do not interrupt fuel-oil service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary fuel-oil supply according to requirements indicated:

1. Notify DEN Project Manager no fewer than five (5) days in advance of proposed interruption of fuel-oil service.
2. Do not proceed with interruption of fuel-oil service without DEN Project Manager's written permission.

PART 2 PRODUCTS

2.01 PIPES, TUBES, AND FITTINGS

Use of copper tubing for fuel -oil piping at DEN is not allowed.

PART 3 EXECUTION

Designer to include high performance paint on exposed fuel piping. Designer to coordinate these requirements with Architect to ensure that appropriate painting requirements are retained in these Divisions 09 section.

3.01 CONNECTIONS

A. Install flanges in piping, NPS 2-1/2 and larger, at final connections of equipment and elsewhere as indicated. It is not allowable to install flange connections in the pipe run in the absence of an inline flanged component or equipment termination.

Section 231123 Facility Natural-Gas Piping

PART 1 GENERAL

Delegated design of Natural-Gas Piping is not allowed at DEN. Remove all references to delegated design of Natural-Gas Piping in Specifications.

1.01 PERFORMANCE REQUIREMENTS

A. Natural-Gas System Pressures within Buildings: Two pressure ranges. Primary pressure is more than 0.5 psig but not more than 2 psig and is reduced to secondary pressure of 0.5 psig or less.

B. Design values of fuel gas supplied for these systems are as follows:

1. Nominal Heating Value: 834 Btu/ 1,000 cu. ft.
2. Nominal Specific Gravity: 0.65.

1.02 FIELD CONDITIONS

A. Interruption of Existing Natural-Gas Service: Do not interrupt natural-gas service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary natural-gas supply according to requirements indicated:

1. Notify DEN Project Manager no fewer than five (5) days in advance of proposed interruption of fuel-oil service.
2. Do not proceed with interruption of natural-gas service without DEN Project Manager's written permission.

1.03 CLOSEOUT SUBMITTALS

A. Contractor shall submit fully dimensioned spool drawings for all welded piping work. Drawings shall indicate all weld types, sizes, and materials to be used. Drawings to be submitted in current DEN approved format as per requirements of Division 01. Other file formats will not be accepted.

PART 2 PRODUCTS

2.01 PIPES, TUBES, AND FITTINGS

Use of copper tubing for fuel -oil piping at DEN is not allowed.

PART 3 EXECUTION

Designer to include high performance paint on exposed fuel piping. Designer to coordinate these requirements with Architect to ensure that appropriate painting requirements are retained in these Division 09 sections.

Natural-Gas piping installed below ground and in slabs is only allowed with written approval from the DEN Mechanical Engineer.

3.01 CONNECTIONS

A. Install flanges in piping, NPS 2-1/2 and larger, at final connections of equipment and elsewhere as indicated. It is not allowable to install flange connections in the pipe run in the absence of an inline flanged component or equipment termination.

Section 232113: Hydronic Piping

PART 1 GENERAL

Grooved Mechanical Couplings: Acceptable only for fire protection piping; not acceptable for any other applications.

Push-on or press-on types of connectors are not allowed.

1.01 FIELD CONDITIONS

A. Interruption of Existing Service: Do not interrupt service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary supply according to requirements indicated:

1. Notify DEN Project Manager no fewer than five (5) days in advance of proposed interruption of service.
2. Do not proceed with interruption of service without DEN Project Manager's written permission.

1.02 CLOSEOUT SUBMITTALS

A. Contractor shall submit fully dimensioned spool drawings for all welded piping work. Drawings shall indicate all weld types, sizes, and materials to be used. Drawings to be submitted in current DEN approved format as per requirements of Division 01. Other file formats will not be accepted.

1.03 PERFORMANCE REQUIREMENTS

Performance requirements in this article are for the piping system. Individual components may have higher pressure or temperature ratings.

A. Hydronic piping components and installation shall be capable of withstanding the following minimum working pressure and temperature unless otherwise indicated:

1. Hot-Water Heating Piping: 160 psig at 250 deg F
2. Chilled-Water Piping: 160 psig at 200 deg F.
3. Dual-Temperature Heating and Cooling Water Piping: 160 psig 250 deg F
4. Condenser-Water Piping: 100 psig at 150 deg F.
5. Filter Backwash Piping: 150 psig at 150 deg F.
6. Makeup-Water Piping: 100 psig at 150 deg F.
7. Condensate-Drain Piping: 150 deg F.
8. Blowdown-Drain Piping: 250 deg F
9. Air-Vent Piping: 250 deg F.
10. Safety-Valve-Inlet and-Outlet Piping: Equal to the pressure of the piping system to which it is attached.

PART 2 PRODUCTS

2.01 COPPER TUBE AND FITTINGS

A. Soft Copper Tube: ASTM B 88, Type K, water tube, annealed temper only.

B. Hard Copper Tube: ASTM B 88, Type L, water tube, drawn temper only.

C. Pressure-Seal Fittings are not allowed.

D. Copper, Mechanically Formed Tee Option: For forming T-branch on copper water tube is allowed with prior approval from DEN Mechanical Engineer.

2.02 PLASTIC PIPE AND FITTINGS

A. Allowed with prior approval from DEM Mechanical Engineer

2.03 FIBERGLASS PIPE AND FITTINGS

A. Allowed with prior approval from DEM Mechanical Engineer

2.04 FLEXIBLE PIPING (FOR PANTOGRAPH PIPING TO PCA UNITS ONLY)

A. TEXCEL GAMMA-FLEX UHMW.

1. Tube: Clear, ultra-high molecular weight polyethylene
2. Cover: Blue or green, EPDM (corrugated)
3. Reinforcement: High tensile tire cord plies; dual helix wire
4. Fluid temperature range: 20°F to 190°F

5. Hose rated working pressure: 200 PSI
6. Fluid: 30%-40% Ethylene Glycol.

PART 3 EXECUTION

3.01 PIPING APPLICATIONS

A. Hydronic piping, aboveground, NPS 2 and smaller, shall be any of the following:

1. Type L drawn-temper copper tubing, wrought-copper fittings, and soldered joints.
2. Schedule 40, Grade B, Type 96 steel pipe fittings; cast-iron flanges and flange fittings; and threaded joints.

B. Hydronic piping, aboveground, NPS 2-1/2 and larger, shall be:

1. Schedule 40 or STD Schedule steel pipe, wrought-steel fittings and wrought-cast or forged-steel flanges and flange fittings, and welded and flanged joints.

3.02 PIPING INSTALLATIONS

Many of the existing systems at DEN can no longer be tested at 1.5 times the systems working pressure. Include alternate, nondestructive testing methods for new systems that tie into existing systems where no other method can be used safely. The use of x-ray testing to evaluate the condition of welds between metallic surfaces according to applicable standards is a possible method of non-destructive testing that may be used. Engineer to evaluate and include in the design documents of the project if necessary to protect existing systems.

Designer to include high perfomance paint on exposed un-insulated steel piping. Designer to coordinate these requirements with Architect to ensure that appropriate painting requirements are retained in these Division 09 sections.

A. Install unions in piping, NPS 2 and smaller, adjacent to valves, at final connections of equipment, and elsewhere as indicated.

B. Install flanges in piping, NPS 2-1/2 and larger, at final connections of equipment and elsewhere as indicated. It is not allowable to install flange connections in the pipe run in the absence of an inline flanged component or equipment termination.

C. Hydronic systems that connect to the central plant heating and/or chilled water distribution systems need to be filled and treated with chemicals matching the CUP’s chemicals after passing all required inspections, pressure tests and flushing. Provide water treatment chemical analysis and pressure test results and obtain written approval from the CUP supervisor prior to opening valves to the CUP water distribution systems. The CUP heating and/or chilled water is not to be used for filling systems. For smaller piping systems the central plant water distribution system may be used for filling with written pre-approval from the CUP supervisor.

D. PCA hydronic systems that connect to the central PCA plant’s Dual-Temperature Heating and Cooling Water distribution system needs to be filled and treated with chemicals matching the PCA plant’s chemicals after passing all required inspections, pressure tests and flushing. Due to the below freezing temperatures that the Dual-Temperature Heating and Cooling Water Piping system operates at, all new, modified, and repaired distribution systems are to be filled with an Ethylene glycol/water mixture. The Ethylene Glycol is to match the systems chemical type and proportions as directed by the CUP supervisor, and circulated for a minimum of 24 hours through all equipment to insure thorough mixing. Provide water treatment chemical analysis and pressure test results and obtain written approval from the CUP supervisor prior to opening valves to the central PCA plant glycol water distribution systems. The central PCA plant’s glycol water distribution system is not to be used for filling new, modified, or repaired systems. For smaller piping systems, the central PCA plant’s glycol water distribution system may be used for filling with written pre-approval from the CUP supervisor.

E. No couplings or splices allowed in flexible piping with-in pantograph arms.

3.03 LEAK TESTING

A. Provide temporary equipment for testing, including pump and gages. Test piping system before insulation is installed, wherever feasible, and remove control devices before testing. Subject entire piping systems to leak tests, either as a whole, or in sections; but leave no part untested.

B. Provide paddle blind or blind flanges at existing valves or connections to the existing systems to protect existing piping from being subject to test pressures.

Section 232113.13: Underground Hydronic Piping

Hydronic piping installed below ground and in slabs is only allowed with written approval from the DEN Mechanical Engineer.

Section 232116: Hydronic Piping Specialties

PART 1 GENERAL

1.01 PERFORMANCE REQUIREMENTS

Performance requirements in this article are for the piping system. Individual components may have higher pressure or temperature ratings.

A. Hydronic piping components and installation shall be capable of withstanding the following minimum working pressure and temperature unless otherwise indicated:

1. Hot-Water Heating Piping: 160 psig at 250 deg F
2. Chilled-Water Piping: 160 psig at 200 deg F.
3. Dual-Temperature Heating and Cooling Water Piping: 160 psig 250 deg F
4. Condenser-Water Piping: 160 psig at 200 deg F.
5. Makeup-Water Piping: 80 psig at 150 deg F.
6. Condensate-Drain Piping: 150 deg F.
7. Blowdown-Drain Piping: 250 deg F
8. Air-Vent Piping: 250 deg F.
9. Safety-Valve-Inlet and-Outlet Piping: Equal to the pressure of the piping system to which it is attached.

PART 2 PRODUCTS

2.01 STRAINERS

A. Manufacturers:

1. Keckley Company.
2. Metraflex Company (The).
3. Titan Flow Control, Inc.
4. Or by prior approval.

B. Y-Pattern type preferred but depends on application.

2.02 CONNECTORS

A. Manufacturers:

1. Keckley Company.
2. Metraflex Company (The).
3. Or by prior approval.

Section 232123: Hydronic Pumps

PART 1 GENERAL

Delegated design of Hydronic Pumps is not allowed at DEN. Remove all references to delegated design of Hydronic Pumps in Specifications.

1.01 ACTION SUBMITTALS

A. Millwright's Certificate: Certify that base mounted pumps have been aligned.

1.02 QUALITY ASSURANCE

A. Source Limitations: Obtain hydronic pumps through one source from a single manufacturer.

B. Product Options: Drawings indicate size, profiles, and dimensional requirements of hydronic pumps and are based on the specific system indicated. Refer to Division 1.

C. Manufacturer: Company specializing in manufacture, assembly, and field performance of pumps with minimum of five (5) years experience.

D. Alignment: Base mounted pumps shall be aligned by qualified millwright.

E. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

F. UL Compliance: Comply with UL 778 for motor-operated water pumps.

1.03 COORDINATION

A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 3.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Deliver, store, protect, and handle products under provisions of Division 1.

B. Manufacturer's Preparation for Shipping: Clean flanges and exposed machined metal surfaces and treat with anticorrosion compound after assembly and testing. Protect flanges, pipe openings, and nozzles with wooden flange covers or with screwed-in plugs.

C. Store pumps in clean, dry location.

D. Retain protective covers for flanges and protective coatings during storage. Maintain in place until installation.

E. Protect bearings and couplings against damage from sand, grit, and other foreign matter.

F. Comply with pump manufacturer's written rigging instructions.

PART 2 PRODUCTS

For each pump type, add the following under the Motor subsection:

Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

Edit the Pump Construction and Motor to suit the project. Confirm with DEN Mechanical Engineer and Project Manager.

Include high performance shaft seals in pump specification and include a spare set for each pump.

2.01 CLOSE-COUPLED, IN-LINE CENTRIFUGAL PUMPS

A. Pump Construction:

1. Pump Bearings: [Permanently lubricated ball bearings] [Oil lubricated; bronze-journal or thrust type].

B. Motor:

1. Motor Bearings: [Permanently lubricated] [Grease-lubricated] ball bearings.

2.02 CLOSE-COUPLED, END-SUCTION CENTRIFUGAL PUMPS

A. Pump Construction:

1. Pump Bearings: [Permanently lubricated ball bearings] [Oil lubricated; bronze-journal or thrust type].

B. Motor:

1. Motor Bearings: [Permanently lubricated] [Grease-lubricated] ball bearings.

2.03 SEPARATELY COUPLED, HORIZONTALLY MOUNTED, IN-LINE CENTRIFUGAL PUMPS

A. Motor:

1. Motor Bearings: [Permanently lubricated] [Grease-lubricated] ball bearings.

2.04 SEPARATELY COUPLED, VERTICALLY MOUNTED, IN-LINE CENTRIFUGAL PUMPS

A. Pump Construction:

1. Pump Bearings: [Permanently lubricated ball bearings] [Oil lubricated; bronze-journal or thrust type].

B. Motor:

1. Motor Bearings: [Permanently lubricated] [Grease-lubricated] ball bearings.

2.05 SEPARATELY COUPLED, BASE-MOUNTED, END-SUCTION CENTRIFUGAL PUMPS

A. Motor:

1. Motor Bearings: [Permanently lubricated] [Grease-lubricated] ball bearings.

2.06 SEPARATELY COUPLED, BASE-MOUNTED, DOUBLE-SUCTION CENTRIFUGAL PUMPS

A. Motor:

1. Motor Bearings: Grease-lubricated.

2.07 SEPARATELY COUPLED, BASE-MOUNTED, END-SUCTION CENTRIFUGAL PUMPS

A. Motor:

1. Motor Bearings: Grease-lubricated.

2.08 SEPARATELY COUPLED, VERTICALLY MOUNTED, TURBINE CENTRIFUGAL PUMPS

A. Motor:

1. Motor Bearings: Grease-lubricated.

PART 3 EXECUTION

3.01 PERFORMANCE REQUIREMENTS

A. Ensure pumps operate at specified system fluid temperatures without vapor binding and cavitation, are non-overloading in parallel or individual operation, and operate within 25 percent of midpoint of published maximum efficiency curve.

3.02 INSTALLATION

A. Engage a qualified millwright to check, align, and certify separately coupled pumps prior to start-up.

3.03 CONCRETE BASES

DEN Requires all connections to structure to be fully detailed by Licensed Colorado Professional Engineer. Designer shall include all information in Project Specifications and Contract Drawings to fully detail base and connections to structure.

Deferred design of equipment supports is not allowed at DEN.

3.04 STARTUP SERVICE

Contractor shall engage a factory-authorized service representative to perform startup service.

3.05 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain hydronic pumps.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 232300: Refrigerant Piping

PART 1 GENERAL

1.01 FIELD CONDITIONS

A. Interruption of Existing Service: Do not interrupt service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary supply according to requirements indicated:

1. Notify DEN Project Manager no fewer than five (5) days in advance of proposed interruption of service.
2. Do not proceed with interruption of service without DEN Project Manager's written permission.

1.02 CLOSEOUT SUBMITTALS

A. Contractor shall submit fully dimensioned spool drawings for all welded piping work. Drawings shall indicate all weld types, sizes, and materials to be used. Drawings to be submitted in current DEN approved format as per requirements of Division 01. Other file formats will not be accepted.

1.03 PRODUCT STORAGE AND HANDLING

A. Dehydrate and charge components such as piping and receivers, seal prior to shipment, until connected into system.

B. Deliver and store piping and specialties in shipping containers with labeling in place.

PART 2 PRODUCTS

2.01 VALVES AND SPECIALTIES

A. Electronic Expansion Valves:

1. Valve:
   a. Brass body with flared or solder connection, needle valve with floating needle and machined seat, stepper motor drive.
   b. Electrical Characteristics: 12 VA, 12 volts DC.

B. Evaporation Control System:

a. Electronic microprocessor based unit in enclosed case, proportional integral control with adaptive superheat, maximum operating pressure function, preselection allowance for electrical defrost and hot gas bypass.

b. Electrical Characteristics: 12 VA, 115 volts, single phase, 50/60 Hz.

C. Refrigeration System Control: Electronic microprocessor based unit in enclosed case, with proportional integral control of valve, on/off thermostat, air temperature alarm (high and low), solenoid valve control, liquid injection adaptive superheat control, maximum operating pressure function, night setback thermostat, timer for defrost control.

PART 3 EXECUTION

3.01 SYSTEM- GENERAL

A. Liquid Indicators:

1. Use line size liquid indicators in main liquid line leaving condenser.
2. If receiver is provided, install in liquid line leaving receiver.
3. Use line size on leaving side of liquid solenoid valves.

B. Valves:

1. Use service valves on suction and discharge of compressors.
2. Use gage taps at compressor inlet and outlet.
3. Use gage taps at hot gas bypass regulators, inlet and outlet.
4. Use check valves on compressor discharge.
5. Use check valves on condenser liquid lines on multiple condenser systems.

C. Refrigerant Charging (Packed Angle) Valve: Use in liquid line between receiver shut-off valve and expansion valve.

D. Strainers:

1. Use line size strainer upstream of each automatic valve.
2. Where multiple expansion valves with integral strainers are used, use single main liquid line strainer.
3. On steel piping systems, use strainer in suction line.
4. Use shut-off valve on each side of strainer.

E. Permanent Filter-Driers:

1. Use in low temperature systems.
2. Use in systems utilizing hermetic compressors.
3. Use filter-driers for each solenoid valve.

F. Replaceable Cartridge Filter-Driers:

1. Use vertically in liquid line adjacent to receivers.
2. Use filter-driers for each solenoid valve.
3. Provide isolation valves and bypass valve for each filter-drier.

G. Solenoid Valves:

1. Use in liquid line of systems operating with single pump-out or pump-down compressor control.
2. Use in liquid line of single or multiple evaporator systems, upstream of each expansion valve.
3. Use in oil bleeder lines from flooded evaporators to stop flow of oil and refrigerant into the suction line when system shuts down.

H. Flexible Connectors: Utilize at or near compressors where piping configuration does not absorb vibration.

3.02 FIELD QUALITY CONTROL

A. Test Witnesses: System testing shall be witnessed by DEN Mechanical Inspector, DEN Project Manager and/or a DEN appointed representative. Provide a written request for testing a minimum of 72 hours prior to test.

Section 232500: HVAC Water Treatment

Engineer is to include water treatment for any hydronic system at DEN. Include the appropriate sections as the project requires. For similar systems where water from the central plant is used for filling, water treatment may be omitted with written permission from the DEN Mechanical Engineer.

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Product Data: Include rated capacities, water-pressure drops, shipping, installed and operating weights, operating characteristics, connection requirements, and furnished specialties and accessories.

B. Shop Drawings: Pretreatment and chemical treatment equipment showing tanks, maintenance space required, and piping connections to hydronic systems.

1. Include plans, elevations, sections, and attachment details.
2. Indicate system schematic, equipment locations, and controls schematics, electrical characteristics, and connection requirements.
3. Include diagrams for power, signal, and control wiring.

1.02 INFORMATIONAL SUBMITTALS

A. Water Analysis Provider Qualifications: Verification of experience and capability of HVAC water-treatment service provider.

B. Field quality-control reports. Indicate start-up of treatment systems when completed and operating properly. Indicate analysis of system water after cleaning and after treatment.

C. Submit for letter of compliance from DEN Project Manager indicating approval of chemicals and their proposed disposal.

D. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project Site.

E. Other Informational Submittals:

1. Water-Treatment Program: Written sequence of operation on an annual basis for the application equipment required to achieve water quality defined in “Performance Requirements” Article.
2. Water Analysis: Illustrate water quality available at Project site.
3. Passivation Confirmation Report: Verify passivation of galvanized steel surfaces, and confirm this observation in a letter to the DEN Project Manager.

1.03 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For sensors, injection pumps, water softeners, RO equipment, water filtration units, and controllers to include in emergency, operation, and maintenance manuals.

1. Include data on chemical feed pumps, agitators, and other equipment including spare parts lists, procedures, and treatment programs. Include step-by-step instructions on test procedures including target concentrations.

Verify requirements for as-built plans with DEN Project Manager.

B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 “Submittal Procedures”.

1. Record actual locations of equipment and piping, including sampling points and location of chemical injectors.

1.04 MAINTENANCE MATERIALS

Maintenance materials may not be allowed on publicly funded projects. Coordinate maintenance material submittal requirements with DEN Project Manager.

A. Provide sufficient chemicals for treatment and testing during warranty period.

1.05 MAINTENANCE SERVICE

Verify with DEN Project Manager that maintenance service is required for Project.

A. Provide monthly technical service visits to perform field inspections and make water analysis on site. Detail findings in writing on proper practices, chemical treating requirements, and corrective actions needed. Submit two (2) copies of field service report after each visit.

B. Provide laboratory and technical assistance services during this maintenance period.

C. Provide onsite inspections of equipment during scheduled or emergency shutdown to properly evaluate success of water treatment program, and make recommendations in writing based upon these inspections.

D. Scope of Maintenance Service: Provide chemicals and service program to maintain water conditions required above to inhibit corrosion and scale formation for hydronic piping and equipment. Services and chemicals shall be provided for a period of one (1) year from date of Substantial Completion and shall include the following:

1. Initial water analysis and HVAC water-treatment recommendations.
2. Startup assistance for Contractor to flush the systems, clean with detergents, and initially fill systems with required chemical treatment prior to operation.
3. Periodic field service and consultation.
4. Customer report charts and log sheets.
5. Laboratory technical analysis.
6. Analyses and reports of all chemical items concerning safety and compliance with government regulations.

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 WATER ANALYSIS

A. Perform an analysis of supply water to determine quality of water available at Project site.

3.02 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

3.03 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor to train Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 232513: Water Treatment for Closed-Loop Hydronic Systems

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Product Data: Include rated capacities, water-pressure drops, shipping, installed and operating weights, operating characteristics, connection requirements, and furnished specialties and accessories.

B. Shop Drawings: Pretreatment and chemical treatment equipment showing tanks, maintenance space required, and piping connections to hydronic systems.

1. Include plans, elevations, sections, and attachment details.
2. Indicate system schematic, equipment locations, and controls schematics, electrical characteristics, and connection requirements
3. Include diagrams for power, signal, and control wiring.

1.02 INFORMATIONAL SUBMITTALS

A. Water Analysis Provider Qualifications: Verification of experience and capability of HVAC water-treatment service provider.

1. Field quality-control reports. Indicate start-up of treatment systems when completed and operating properly. Indicate analysis of system water after cleaning and after treatment.

B. Submit for letter of compliance from DEN Project Manager indicating approval of chemicals and their proposed disposal.

C. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project Site.

D. Other Informational Submittals:

1. Water-Treatment Program: Written sequence of operation on an annual basis for the application equipment required to achieve water quality defined in “Performance Requirements” Article.

2. Water Analysis: Illustrate water quality available at Project site

1.03 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For sensors, injection pumps, and controllers to include in emergency, operation, and maintenance manuals.

1. Include data on chemical feed pumps, agitators, and other equipment including spare parts lists, procedures, and treatment programs. Include step-by-step instructions on test procedures including target concentrations.

Verify requirements for as-built plans with DEN Project Manager.

B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 “Submittal Procedures”.

1. Record actual locations of equipment and piping, including sampling points and location of chemical injectors

1.04 MAINTENANCE MATERIALS

Maintenance materials may not be allowed on publicly funded projects. Coordinate maintenance material submittal requirements with DEN Project Manager.

A. Provide sufficient chemicals for treatment and testing during warranty period.

1.05 MAINTENANCE SERVICE

Verify with DEN Project Manager that maintenance service is required for Project.

A. Provide monthly technical service visits to perform field inspections and make water analysis on site. Detail findings in writing on proper practices, chemical treating requirements, and corrective actions needed. Submit two (2) copies of field service report after each visit.

B. Provide laboratory and technical assistance services during this maintenance period.

C. Provide onsite inspections of equipment during scheduled or emergency shutdown to properly evaluate success of water treatment program, and make recommendations in writing based upon these inspections.

D. Scope of Maintenance Service: Provide chemicals and service program to maintain water conditions required above to inhibit corrosion and scale formation for hydronic piping and equipment. Services and chemicals shall be provided for a period of one (1) year from date of Substantial Completion and shall include the following:

1. Initial water analysis and HVAC water-treatment recommendations.
2. Startup assistance for Contractor to flush the systems, clean with detergents, and initially fill systems with required chemical treatment prior to operation.
3. Periodic field service and consultation.
4. Customer report charts and log sheets.
5. Laboratory technical analysis.
6. Analyses and reports of all chemical items concerning safety and compliance with government regulations.

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 WATER ANALYSIS

A. Perform an analysis of supply water to determine quality of water available at Project site.

3.02 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

3.03 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor to train Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

B. Training: Provide a "how-to-use" self-contained breathing apparatus video that details exact operating procedures of equipment.

Section 232516: Water Treatment for Open-Loop Hydronic Systems

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Product Data: Include rated capacities, water-pressure drops, shipping, installed and operating weights, operating characteristics, connection requirements, and furnished specialties and accessories.

B. Shop Drawings: Pretreatment and chemical treatment equipment showing tanks, maintenance space required, and piping connections to hydronic systems.

1. Include plans, elevations, sections, and attachment details.
2. Indicate system schematic, equipment locations, and controls schematics, electrical characteristics, and connection requirements
3. Include diagrams for power, signal, and control wiring.

1.02 INFORMATIONAL SUBMITTALS

A. Water Analysis Provider Qualifications: Verification of experience and capability of HVAC water-treatment service provider.

B. Field quality-control reports. Indicate start-up of treatment systems when completed and operating properly. Indicate analysis of system water after cleaning and after treatment.

C. Submit for letter of compliance from DEN Project Manager indicating approval of chemicals and their proposed disposal.

D. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project Site.

E. Other Informational Submittals:

1. Water-Treatment Program: Written sequence of operation on an annual basis for the application equipment required to achieve water quality defined in "Performance Requirements" Article.
2. Water Analysis: Illustrate water quality available at Project site

1.03 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For sensors, injection pumps, and controllers to include in emergency, operation, and maintenance manuals.

1. Include data on chemical feed pumps, agitators, and other equipment including spare parts lists, procedures, and treatment programs. Include step-by-step instructions on test procedures including target concentrations.

Verify requirements for as-built plans with DEN Project Manager.

B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 "Submittal Procedures".

1. Record actual locations of equipment and piping, including sampling points and location of chemical injectors.

1.04 MAINTENANCE MATERIALS

Maintenance materials may not be allowed on publicly funded projects. Coordinate maintenance material submittal requirements with DEN Project Manager.

A. Provide sufficient chemicals for treatment and testing during warranty period.

1.05 MAINTENANCE SERVICE

Verify with DEN Project Manager that maintenance service is required for Project.

A. Provide monthly technical service visits to perform field inspections and make water analysis on site. Detail findings in writing on proper practices, chemical treating requirements, and corrective actions needed. Submit two (2) copies of field service report after each visit.

B. Provide laboratory and technical assistance services during this maintenance period.

C. Provide onsite inspections of equipment during scheduled or emergency shutdown to properly evaluate success of water treatment program, and make recommendations in writing based upon these inspections.

D. Scope of Maintenance Service: Provide chemicals and service program to maintain water conditions required above to inhibit corrosion and scale formation for hydronic piping and equipment. Services and chemicals shall be provided for a period of one (1) year from date of Substantial Completion and shall include the following:

1. Initial water analysis and HVAC water-treatment recommendations.
2. Startup assistance for Contractor to flush the systems, clean with detergents, and initially fill systems with required chemical treatment prior to operation.
3. Periodic field service and consultation.
4. Customer report charts and log sheets.
5. Laboratory technical analysis.
6. Analyses and reports of all chemical items concerning safety and compliance with government regulations.

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 WATER ANALYSIS

A. Perform an analysis of supply water to determine quality of water available at Project site.

3.02 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.

3.03 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor to train Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

B. Training: Provide a “how-to-use” self-contained breathing apparatus video that details exact operating procedures of equipment.

Section 232519: Water Treatment for Steam System Feedwater

DEN does not use steam for heating systems and has no specific requirements other than those listed in Division 230400 and 230500.

Section 232523: Water Treatment for Humidification Steam System Feedwater

DEN does not use steam for heating systems and has no specific requirements other than those listed in Division 230400 and 230500.

Section 232533: HVAC Makeup-Water Filtration Equipment

PART 1 GENERAL

1.01 INFORMATIONAL SUBMITTALS

A. Submit certificate of compliance from authority having jurisdiction indicating approval of chemicals and their proposed disposal.

B. Water Analysis: Submit a copy of the water analysis to illustrate water quality available at Project Site.

C. Other Informational Submittals:

1. Water Analysis: Illustrate water quality available at Project site.

1.02 CLOSEOUT SUBMITTALS

A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 “Submittal Procedures”.

1. Record actual locations of equipment and piping, including sampling points and location of chemical injectors.

1.03 QUALITY ASSURANCE

See Section 014000 “Quality Requirements” for a definition of the term “experienced.”

A. HVAC Water-Treatment Service Provider Qualifications: An experienced HVAC water-filtration service provider capable of analyzing water qualities, installing water-filtration equipment, and applying water filtration as specified in this Section.

B. Installer Qualifications: An experienced installer who is an authorized representative of the chemical treatment manufacturer for both installation and maintenance of chemical treatment equipment required for this Project with minimum of three (3) years experience.

C. Manufacturers: Companies specializing in manufacturing the products specified in this Section with minimum of five (5) years documented experience. Companies shall have local representatives with water analysis laboratories and full time service personnel.

D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

E. Conform to applicable code for addition of non-potable chemicals to building mechanical systems, and for to public sewage systems.

F. Products Requiring Electrical Connection: Listed and classified by Underwriters' Laboratories, Inc. (or other testing agency acceptable to the authority having jurisdiction) as suitable for the purpose specified and indicated.

1.04 MAINTENANCE SERVICE

Verify with Owner that maintenance service is required for Project.

A. Provide monthly technical service visits to perform field inspections and make water analysis on site. Detail findings in writing on proper practices, chemical treating requirements, and corrective actions needed. Submit two (2) copies of field service report after each visit.

B. Provide laboratory and technical assistance services during this maintenance period.

C. Provide onsite inspections of equipment during scheduled or emergency shutdown to properly evaluate success of water treatment program, and make recommendations in writing based upon these inspections.

D. Scope of Maintenance Service: Provide chemicals and service program to maintain water conditions required above to inhibit corrosion, scale formation, and biological growth for equipment. Services and chemicals shall be provided for a period of one (1) year from date of Substantial Completion, and shall include the following:

1. Periodic field service and consultation.
2. Customer report charts and log sheets.
3. Laboratory technical analysis.
4. Analyses and reports of all chemical items concerning safety and compliance with government regulations.

1.05 WARRANTY

Coordinate warranty requirements with DEN Project Manager.

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 WATER ANALYSIS

A. Perform an analysis of supply water to determine quality of water available at Project site.

3.02 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain HVAC water-treatment systems and equipment.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 233113: Metal Ducts

PART 1 GENERAL

1.01 PERFORMANCE REQUIREMENTS

A. No variation of duct configuration or sizes permitted except by written permission of the DEN Mechanical Engineer. Size round ducts installed in place of rectangular ducts in accordance with SMACNA or ASHRAE table of equivalent rectangular and round ducts.

B. Airstream Surfaces: Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.

1.02 CLOSEOUT SUBMITTALS

Verify requirements for as-built plans with DEN Project Manager.

A. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 “Submittal Procedures”.

1. Record actual locations of ducts and duct fittings. Record changes in fitting location and type. Show additional fittings used.

1.03 QUALITY ASSURANCE

A. Perform Work in accordance with SMACNA- HVAC Duct Construction Standards- Metal and Flexible.

B. Maintain one printed copy of document on site for reference by Contractor's personnel.

C. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5- “Systems and Equipment” and Section 7- “Construction and System Start-up.”

PART 2 PRODUCTS

2.01 MATERIALS

Material selection for ductwork shall take into consideration radiated noise.

A. General: Comply with SMACNA's “HVAC Duct Construction Standards--Metal and Flexible” for acceptable materials, material thicknesses, and duct construction methods, unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

B. Duct Board ductwork is not allowed at DEN.

2.02 DUCTWORK FABRICATION

A. Fabricate and support in accordance with SMACNA HVAC Duct Construction Standards- Metal and Flexible, and as indicated. Provide duct material, gages, reinforcing, and sealing for operating pressures indicated, but not less than 1" WG positive and negative pressures.

B. Construct T's, bends, and elbows with radius of not less than 1-1/2 times width of duct on centerline. Where not possible and where rectangular elbows are used, provide turning vanes. Where acoustical lining is indicated, provide turning vanes of perforated metal with glass fiber insulation.

C. Increase duct sizes gradually, not exceeding 15 degrees divergence wherever possible; maximum 30 degrees divergence upstream of equipment and 45 degrees convergence downstream.

D. Fabricate continuously welded round and oval duct fittings two gages heavier than duct gages indicated in SMACNA Duct Construction Standards. Joints shall be minimum 4 inch cemented slip joint, brazed or electric welded. Prime coat welded joints.

E. Provide standard 45 degree lateral wye takeoffs.

F. 90 degree conical tee connections (spin-in fittings) may only be used downstream of a VAV terminal.

2.03 MANUFACTURED DUCTWORK AND FITTINGS

A. Manufacture in accordance with SMACNA HVAC Duct Construction Standards-Metal and Flexible, and as indicated. Provide duct material, gages, reinforcing, and sealing for operating pressures indicated.

B. SMANCA Type 1 offset transitions shall not be allowed without written approval from DEN Project Manager or DEN Mechanical Inspector.

2.04 BURIED UNDERGROUND DUCTS

Buried underground ductwork is only allowed with written approval from the DEN Project Manager.

2.05 HANGERS AND SUPPORTS

Wire and cable hangers are not allowed at DEN. Remove all references to wire and cable supports from specifications.

PART 3 EXECUTION

3.01 DUCT CLEANING

Verify requirements for existing duct cleaning with DEN Project Manager.

A. Clean new and existing duct system(s) before testing, adjusting, and balancing.

B. Clean ductwork internally, unit-by-unit as it is installed, of dust and debris. Clean external surfaces of foreign substances, which might cause corrosive deterioration of metal or, where ductwork is to be painted, might interfere with painting or cause paint deterioration.

C. Strip protective paper from stainless ductwork surfaces, and repair finish wherever it has been damaged.

D. Temporary Closure: At ends of ducts, which are not connected to equipment or air distribution devices at time of ductwork installation, provide temporary closure of polyethylene film or other covering, which will prevent entrance of dust and debris until time connections are to be completed.

E. Mark position of dampers and air-directional mechanical devices before cleaning and perform cleaning before air balancing.

F. Cleanliness Verification:

1. Visually inspect metal ducts for contaminants.
2. Where contaminants are discovered, re-clean, and reinspect ducts.

3.02 CLEANING EXISTING SYSTEMS

A. Use service openings, as required, for physical and mechanical entry and for inspection.

1. Use existing service openings where possible.
2. Create other openings to comply with duct standards.
3. Disconnect flexible ducts as needed for cleaning and inspection.
4. Remove and reinstall ceiling sections to gain access during the cleaning process.

B. Mark position of dampers and air-directional mechanical devices before cleaning and restore to their marked position on completion.

C. Particulate Collection and Odor Control:

1. When venting vacuuming system inside the building, use HEPA filtration with 99.97% collection efficiency for 0.3-micron size (or larger) particles.
2. When venting vacuuming system to the outside, use filtration to contain debris removed from HVAC system, and locate exhaust down wind and away from air intakes and other points of entry into building.

D. Clean the following metal duct systems by removing surface contaminants and deposits:

1. Air outlets and inlets (registers, grilles, and diffusers).
2. Supply, return, and exhaust fans including fan housings, plenums (except ceiling supply and return plenums), scrolls, blades or vanes, shafts, baffles, dampers, and drive assemblies.

3. Air-handling unit internal surfaces and components including mixing box, coil section, air wash systems, spray eliminators, condensate drain pans, humidifiers and dehumidifiers, filters and filter sections, and condensate collectors and drains.
4. Coils and related components.
5. Return-air ducts, dampers, and actuators except in ceiling plenums and mechanical equipment rooms.
6. Supply-air ducts, dampers, actuators, and turning vanes.
7. Dedicated exhaust and ventilation components and makeup air systems.

E. Mechanical Cleaning Methodology:

1. Clean metal duct systems using mechanical cleaning methods that extract contaminants from within duct systems and remove contaminants from building.
2. Use vacuum-collection devices that are operated continuously during cleaning. Connect vacuum device to downstream end of duct sections so areas being cleaned are under negative pressure.
3. Use mechanical agitation to dislodge debris adhered to interior duct surfaces without damaging integrity of metal ducts, duct liner, or duct accessories.
4. Clean fibrous-glass duct liner with HEPA vacuuming equipment; do not permit duct liner to get wet. Replace fibrous-glass duct liner that is damaged, deteriorated, or delaminated or that has friable material, mold, or fungus growth.
5. Clean coils and coil drain pans according to NADCA 1992. Keep drain pan operational. Rinse coils with clean water to remove latent residues and cleaning materials; comb and straighten fins.
6. Provide operative drainage system for washdown procedures.
7. Biocidal Agents and Coatings: Apply biocidal agents if fungus is present. Apply biocidal agents according to manufacturer's written instructions after removal of surface deposits and debris.

F. Cleanliness Verification:

1. Verify cleanliness after mechanical cleaning and before application of treatment, including biocidal agents and protective coatings.
2. Visually inspect metal ducts for contaminants.
3. Where contaminants are discovered, re-clean and reinspect ducts.

G. Verification of Coil Cleaning: Cleaning must restore coil pressure drop to within 10% of pressure drop measured when coil was first installed. If original pressure drop is not known, coil will be considered clean only if it is free of foreign matter and chemical residue, based on thorough visual inspection.

3.03 FINAL CLEANING

A. Clean duct system and force air at high velocity through duct to remove accumulated dust. To obtain sufficient air, clean half the system at a time. Protect equipment, which may be harmed by excessive dirt with temporary filters, or bypass during cleaning.

B. Clean duct systems with high power vacuum machines. Protect equipment, which may be harmed by excessive dirt with filters, or bypass during cleaning. Provide adequate access into ductwork for cleaning purposes.

Section 233300: Air Duct Accessories

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Product Data: For each type of product.

1. For duct silencers, include dimension data, materials, pressure drop and dynamic insertion loss data. Include breakout noise calculations for high transmission loss casings.

1.02 INFORMATIONAL SUBMITTALS

A. Test Reports: Indicate acoustic housings meet or exceed specified sound transmission loss values.

1.03 QUALITY ASSURANCE

A. Conform to City and County of Denver code for sound levels at property line.

PART 2 PRODUCTS

2.01 MATERIALS

DEN does not use Pneumatic actuators. Remove all references to Pneumatic Actuators in Specifications.

2.02 DUCT SECURITY BARS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Carnes
2. KEES, Inc.
3. Lloyd Industries, Inc.
4. Metal Form Manufacturing, Inc.
5. Price Industries
6. Or approved equivalent

B. Description: Field- or factory-fabricated and field-installed duct security bars.

C. Configuration:

1. Frame: 2 by 1/4 inch (51 by 6 mm) flat frame
2. Sleeve: 0.1345-inch 3.4-mm, continuously welded steel frames with 2-1/2-by-2-1/2-by-1/4-inch (25-by-25-by-4.8-mm angle frame furnished loose for field welding on other end. To be poured in place or set with concrete block or welded or bolted to wall, one side only. Duct connections on both sides.
3. Horizontal Bars: 1/2 inch(13 mm)
4. Vertical Bars: 1/2 inch (13 mm)
5. Bar Spacing: 6 inches (150 mm)
6. Mounting: Ductwork or other framing

PART 3 EXECUTION

3.01 PREPARATION

A. Verify that electric power is available and of the correct characteristics.

3.02 INSTALLATION

A. Fire, Smoke and combination Fire and smoke dampers:

1. Indicate locations of each on the drawings. “Where required by authorities” is not good practice and will not be accepted by DEN.
2. Demonstrate re-setting of fire dampers to DEN Project Manager's representative.

B. Indicate locations of balancing dampers at points on supply, return, and exhaust systems where branches are taken from larger ducts as required for air balancing. Install minimum 2 duct widths from duct take-off.

C. Indicate locations of e balancing dampers on duct take-off to diffusers, grilles, and registers, regardless of whether dampers are specified as part of the diffuser, grille, or register assembly.

D. Indicate locations of duct security bars. Construct duct security bars from 0.164-inch steel sleeve, continuously welded at all joints and 1/2-inch-diameter steel bars, 6 inches o.c. in each direction in center of sleeve. Weld each bar to steel sleeve and each crossing bar. Weld 2-1/2-by-2-1/2-by-1/4-inch steel angle to 4 sides and both ends of sleeve. Connect duct security bars to ducts with flexible connections. Provide 12-by-12-inch hinged access panel with cam lock in duct in each side of sleeve.

3.03 LABELING

Labeling requirements shall not be eliminated from any project.

A. Provide identification and access labels for all fire dampers, smoke dampers and combination fire smoke dampers.

B. Labels shall be plastic with pressure-sensitive, permanent-type, self-adhesive back. Font shall be Arial, with a minimum text height of half an inch. Font color shall be red and background color shall be white.

C. Identification labels shall be located on the damper sleeve or frame on both side of the damper. The label shall indicate “FIRE DAMPER”, “SMOKE DAMPER” and/or “COMBINATION FIRE/SMOKE DAMPER”.

D. Access labels shall be provided to indicate locations for access to reset and maintain the damper. The label shall indicate “FIRE DAMPER ACCESS”, “SMOKE DAMPER ACCESS” and/or “COMBINATION FIRE/SMOKE DAMPER ACCESS”.

1. Access label location shall be as follows:
   a. Damper in continuous duct with duct access with-in 12 inches of the damper:
      1. Labeling shall occur on the duct and on the ceiling below.
      2. Locate label on duct access door.
      3. Locate label on suspended ceiling tile or on access door in hard ceiling.
   b. Damper with removable grille/register on one side:
      1. Locate label on face of grille/register.
   c. Damper in wall with no duct connection:
      1. Locate label on suspended ceiling tile or on access door in hard ceiling.

3.04 FIELD QUALITY CONTROL

A. Manufacturer's field services for duct silencers:

1. Provide services of AABC or NEBB testing agency to take noise measurement. Use meters meeting requirements of ASA 47 (ANSI S1.4).
2. After start-up, final corrections and balancing of systems take octave band sound measurements over full audio frequency range in areas adjacent to mechanical equipment rooms, duct and pipe shafts, and other critical locations, as directed.
3. Provide one-third octave band measurements of artificial sound sources in areas indicated as having critical requirements.
4. Submit complete report of test results including sound curves.

Section 233413: Axial HVAC Fans

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Shop Drawings

1. Include diagrams for power, signal, and control wiring.

a. Differentiate between manufacturer-installed and field-installed wiring.

1.02 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For axial fans to include in emergency, operation, and maintenance manuals.

1. Include instructions for lubrication, motor and drive replacement, spare parts list, and wiring diagrams.

Verify requirements for as-built plans with DEN Project Manager.

B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 “Submittal Procedures”.

PART 2 PRODUCTS

All fan blades and wheels must be made of Black-enameled or galvanized steel, where available, otherwise cast iron shall be used. Remove other fan blade and wheel materials from Specifications.

2.01 PERFORMANCE REQUIREMENTS

A. Belt Drives:

1. Cast iron or steel sheaves, dynamically balanced, keyed. Variable and adjustable pitch sheaves for motors 15 hp and under selected so required rpm is obtained with sheaves set at mid-position; fixed sheave for 20 hp and over, matched belts, and drive rated as recommended by manufacturer or minimum 1.5 times nameplate rating of the motor.

PART 3 EXECUTION

3.01 INSTALLATION

A. Do not operate fans for any purpose until ductwork is clean, filters in place, bearings lubricated, and fan has been test run under observation.

B. Provide safety screen where inlet or outlet is exposed.

C. Provide access to adjustable blade axial fan wheels for varying blade angle setting. Adjust blades for varying range of volume and pressure.

3.02 FIELD QUALITY CONTROL

Contractor shall engage a factory-authorized service representative to perform startup service.

3.03 CLEANING

A. On completion of installation, internally clean fans according to manufacturer's written instructions. Remove foreign material and construction debris. Vacuum fan wheel and cabinet.

B. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.

3.04 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train DEN maintenance personnel to adjust, operate, and maintain axial fans.

B. Train DEN maintenance personnel on procedures and schedules for starting and stopping, troubleshooting, servicing, and maintaining equipment and schedules.

C. Schedule training with DEN Project Manager, with at least seven (7) days' advance notice.

Section 233416: Centrifugal Fans

PART 1 GENERAL

1.01 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For centrifugal fans to include in emergency, operation, and maintenance manuals.

1. Include instructions for lubrication, motor and drive replacement, spare parts list, and wiring diagrams as specified in Section 230400 “Basic HVAC Requirements”.

Verify requirements for as-built plans with DEN Project Manager.

B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 “Submittal Procedures”.

PART 2 PRODUCTS

All fan blades and wheels must be made of Black-enameled or galvanized steel, where available, otherwise cast iron shall be used. Remove other fan blade and wheel materials from Specifications.

2.01 BELT DRIVES:

A. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.

PART 3 EXECUTION

3.01 ENVIRONMENTAL REQUIREMENTS

A. Do not operate fans for any purpose until ductwork is clean, filters in place, bearings lubricated, and fan has been test run under observation.

3.02 CLEANING

A. On completion of installation, internally clean fans according to manufacturer's written instructions. Remove foreign material and construction debris. Vacuum fan wheel and cabinet.

B. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.

3.03 FIELD QUALITY CONTROL

Contractor shall engage a factory-authorized service representative to perform startup service.

3.04 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain centrifugal fans.

B. Train DEN maintenance personnel on procedures and schedules for starting and stopping, troubleshooting, servicing, and maintaining equipment and schedules.

C. Schedule training with DEN Project Manager, with at least seven (7) days' advance notice.

Section 233423: HVAC Power Ventilators

PART 1 GENERAL

1.01 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For centrifugal fans to include in emergency, operation, and maintenance manuals.

1. Include instructions for lubrication, motor and drive replacement, spare parts list, and wiring diagrams as specified in Section 230400 “Basic HVAC Requirements”.

Verify requirements for as-built plans with DEN Project Manager.

B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 “Submittal Procedures”.

PART 2 PRODUCTS

2.01 BELT DRIVES:

A. Motor Pulleys: Adjustable pitch for use with motors through 5 hp; fixed pitch for use with larger motors. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.

PART 3 EXECUTION

3.01 ENVIRONMENTAL REQUIREMENTS

A. Do not operate fans for any purpose until ductwork is clean, filters in place, bearings lubricated, and fan has been test run under observation.

3.02 CLEANING

A. On completion of installation, internally clean fans according to manufacturer's written instructions. Remove foreign material and construction debris. Vacuum fan wheel and cabinet.

B. After completing system installation, including outlet fitting and devices, inspect exposed finish. Remove burrs, dirt, and construction debris and repair damaged finishes.

3.03 FIELD QUALITY CONTROL

Contractor Shall engage a factory authorized service representative to perform startup service.

3.04 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train DEN maintenance personnel to adjust, operate, and maintain power ventilators.

B. Train DEN maintenance personnel on procedures and schedules for starting and stopping, troubleshooting, servicing, and maintaining equipment and schedules.

C. Schedule training with DEN Project Manager, with at least seven (7) days' advance notice.

Section 233600: Air Terminal Units

PART 1 GENERAL

1.01 INFORMATIONAL SUBMITTALS

Coordinate requirements for coordination drawings with DEN Project Manager.

A. Coordination Drawings: Reflected ceiling plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:

1. Ceiling suspension assembly members.
2. Size and location of initial access modules for acoustic tile.
3. Ceiling-mounted items including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.

1.02 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For air terminal units to include in emergency, operation, and maintenance manuals. Include manufacturer's descriptive literature, operating instructions, maintenance and repair data, and parts lists. In addition to items specified in Section 017823 “Operation and Maintenance Data,” include the following:

1. Instructions for resetting minimum and maximum air volumes.
2. Instructions for adjusting software set points.

Verify requirements for as-built plans with DEN Project Manager.

B. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work, in accordance with requirements as specified in Section 013300 “Submittal Procedures”.

1. Record actual locations of units and controls components.

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain air terminal units.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 235113.16: Vent Dampers

PART 1 GENERAL

1.01 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For draft control devices to include in emergency, operation, and maintenance manuals.

PART 2 PRODUCTS

PART 3 EXECUTION

Section 235116: Fabricated Breechings and Accessories

PART 1 GENERAL

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 INSTALLATION OF UNLISTED, FIELD-FABRICATED BREECHINGS

A. At appliances, provide slip joints permitting removal of appliances without removal or dismantling of breechings, breeching insulation, chimneys, or stacks.

Section 235233: Water-Tube Boilers

PART 1 GENERAL

Engineer to use the Design Summary section below for evaluation and selection of equipment used in the design.

1.01 DESIGN SUMMARY

A. Evaluation: Boilers will be evaluated on a "best value" basis considering the following factors.

1. Manufacturer's guaranteed Output Capacity within the space available.
2. Emissions.
3. Life Cycle Cost (LCC) performance.
    a. Total Installed Cost.
    b. Gas consumption at project loads and elevation deration.
    c. Electrical consumption (including fan).
    d. Operation and maintenance costs.
4. Maintainability of boiler layout.
5. Compliance with specification requirements
6. Lead Time to meet or beat 24 weeks lead time from date of approved shop drawings with no more than 2 weeks between award of project and delivery of shop drawings. This requirement to be verified with DEN PM.

B. DEN does not use steam for heating systems.

C. For multiple boiler systems, proposed boilers shall be identical including all ancillary components and equipment.

D. Do not use finned water-tube boilers without written permission from DEN Mechanical Engineer.

E. Boiler total weight including housekeeping pad shall impart no more than 250 lb/sqft while operating if located in the lower level of the CUP. Match existing flue and piping connection points to the greatest extent possible.

F. Design to meet scheduled/specified conditions and for normal operation at elevation of 5,400 ft above sea level.

G. Factory assembled and tested. Partial assembly allowed only as required for access to boiler room. If partial field assembly is required, submit request to DEN Mechanical Engineer for approval.

H. Trim, and accessories for water tube boilers with the following configurations, burners, and outputs:

1. Burner- Combination natural gas and Jet-A fuel burner.
    a. The burner shall be Low NOx emissions, 15 ppm or less when firing on natural gas. Manufacturer shall guarantee output capacity per scheduled contract documents and turndown capacity with NOx compliant operation. Manufacturer is responsible for field verification of guarantees listed above.
    b. Burner shall be fully modulating, minimum 6.5:1 turndown ratio with the following certifications and features:
        1. Remote/automatic fuel switchover between gas and fuel oil.
        2. Burner and Orifices: Stainless steel or Cast iron, for natural gas and Jet-A.
        3. Jet-A fuel supply: Control devices and full-modulating control sequence shall comply with requirements in ASME CSD-1.
        4. Gas Train: Control devices and full-modulation control sequence shall comply with requirements in AGA and ASME CSD-1.

5. Pilot: Intermittent-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.
6. Welded construction with multivane, stainless-steel flame-retention diffuser for natural gas. Mount burner on hinged access door to permit access to combustion chamber.
7. Burner and boiler assembly shall have self-contained ability to atomize Jet Fuel-A for operation, by compressed air or other required means.

2. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor; with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.
   a. Motors: Indicated, large enough so driven load will not require motor to operate in service factor range above 1.0. Motor shall be sized to drive fan at full speed at minimum ambient temperature. Provide inverter duty rated motors.
3. Trim:
   a. Pressure and Temperature Gage: Minimum 3-1/2-inch diameter, combination water-pressure and-temperature gage. Gages shall have operating-pressure and -temperature ranges so normal operating range is about 50 percent of full range.
   b. Manual Boiler Air Vent is preferred.
   c. Minimum NPS 1 hose-end gate valve drain.
   d. ASME rated safety relief valve(s) rated for 150 PSI relief setting.
4. Controls:
   a. Provide listed cable management products, such as cable tray, cable ties, tie mounts, and accessories as required for routing of wiring within enclosures. All wiring within enclosures shall be managed and neatly arranged.
   b. Boiler operating controls shall include the following devices and features per Boiler:
      1. Control transformer.
      2. Set points shall be adjustable.
      3. Hand, off, automatic control to the local boiler.
      4. Interface Screen at the boiler control panel shall be minimum 10” in size (diagonal measurement).
   c. Burner Operating Controls: To maintain safe operating conditions, burner safety controls limit burner operation.
      1. High Cutoff: Automatic reset stops burner if operating conditions rise above maximum boiler design temperature or pressure.
      2. Low-Water Cutoff Switch: Electronic probe shall prevent burner operation on low water. Cutoff switch shall be automatic-reset type. Piping assembly shall not be a dead leg where air may accumulate and cause nuisance trips.
      3. Blocked Vent Safety Switch: Manual-reset switch factory mounted on draft diverter.
      4. Rollout Safety Switch: Factory mounted on boiler combustion chamber.
      5. Audible Alarm: Factory mounted on control panel with silence switch; shall sound alarm for above conditions.
      6. Self-actuating flue damper controls system capable of operating two boilers on a single flue exhaust chimney.
      7. Burner high water output temperature trip setting shall be no lower than 250 degrees F. CUP Heating Water system operates at 230 degrees F supply water temperature.
5. Building Automation System Interface: Factory install hardware and software to enable building automation system to monitor, control, and display boiler status and alarms.
   a. Monitoring: On/off status, firing rate, common trouble alarm and low water level alarm.
   b. Control: On/off operation, hot water supply temperature set-point adjustment.

c. A communication interface with building automation system shall enable building automation system operator to remotely control and monitor the boiler from an operator workstation. Control features available, and monitoring points displayed, locally at boiler control panel shall be available through building automation system.

d. Provide hardwired remote-control capability from BAS to each boiler panel, each boiler shall have dedicated control panel, for on/off and supply water setpoint control.

e. Provide each boiler with necessary hardware for BACnet MSTP output communications protocol.

6. Single-Point Field Power Connection: Factory-installed and-wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to boiler.

1.02 ACTION SUBMITTALS

A. Product Data: Provide data indicating general assembly, components, controls, safety controls, and wiring diagrams with electrical characteristics and connection requirements, and service connections.

1. Include performance data, operating characteristics, furnished specialties, and accessories.
2. Include data substantiating that materials comply with requirements.

B. Shop Drawings: For boilers, boiler trim, and accessories. Include plans, elevations, sections, details, shipped loose components, and attachments to other work.

1. Wiring Diagrams: Power, signal, and control wiring.
2. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
3. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
4. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

1.03 INFORMATIONAL SUBMITTALS

A. Information in this section is required to be submitted at least 2 weeks prior to shipping.

1. Source quality-control test reports.
2. Manufacturer's Certificate: Certify that units meet or exceed specified requirements.
3. Field quality-control test reports. Indicate condition of equipment after start-up including control settings and performance chart of control system.
4. Test Reports: Indicate specified performance and efficiency is met or exceeded. Provide factory combustion test data for substantially identical unit that includes boiler firing rate, overfire draft, gas flow rate, heat input, burner manifold gas pressure, percent carbon monoxide (CO), percent oxygen (O), percent excess air, flue gas temperature at outlet, ambient temperature, net stack temperature, percent stack loss, percent combustion efficiency, and heat output.

1.04 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For boilers, components, and accessories to include in emergency, operation, and maintenance manuals.

1. Include manufacturer's descriptive literature, operating instructions, cleaning procedures, replacement parts list, and maintenance and repair data.
2. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work.

1.05 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace heat exchangers damaged by thermal shock and vent dampers of boilers that fail in materials or workmanship within specified warranty period. This full warranty shall include both repair or replacement parts as needed, and labor to complete said warranty service.

1. Warranty Period for Heat Exchangers: Minimum twenty (20) years from date of Substantial Completion.
2. Warranty Period for Vent Dampers: Minimum Five (5) years from date of Substantial Completion.

B. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace drums, tubes, headers, cabinets, atmospheric gas & fuel burners, control systems, and pressure vessels of boilers that fail in materials or workmanship within specified warranty period. This full warranty shall include both repair or replacement parts as needed, and labor to complete said warranty service.

1. Warranty Period for Drums, Tubes, Headers, Cabinets, Burner, and Control System: Minimum five (5) years from date of Substantial Completion.
2. Warranty Period for Pressure Vessel: Minimum twenty (20) years from date of Substantial Completion, for thermal shock.
3. Warranty Period for Refractory: 5 years from date of Substantial Completion.

C. Coordinate substantial completion milestones with DEN operations for warranty period validation.

PART 2 PRODUCTS

2.01 GENERAL:

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Superior Boiler, LLC
2. Unilux Advanced Manufacturing, LLC
3. or approved equal.

B. Description: Water-tube boiler with heat exchanger sealed pressure tight, built on a steel base; including insulated jacket, flue-gas vent, supply and return connections, and controls.

C. Heat-Exchanger Design: Bent steel tubes swaged or welded into steel headers with membrane waterwall design.

1. Accessible drain and blowdown tapings, both high and low, for surface and mud removal.
2. Accessible inspection ports in drum, mud legs, and tube manifolds.
3. Lifting lugs on top of boiler.
4. Built-in air separator.
5. If water pressure drop varies from schedule, provide new balancing devices for all new and existing boiler installations.

D. Combustion Chamber: Equipped with minimum 4-inch, 2700 deg F poured refractory on floor and minimum 3-1/2-inch lap-jointed cast refractory with fiber-blanket joint seals on side walls. Combustion chamber shall have flame observation ports in front and back. If refractory is not required for boiler design, clarify alternate combustion chamber design in submittal.

E. Casing:

1. Insulation: Minimum 1-inch thick insulating board; galvanized-steel membrane, and minimum 2-inch thick, mineral-fiber insulation surrounding the heat exchanger and combustion chamber, and all external pipes such as FGR.
2. Top Flue Connection: Constructed of stainless or carbon steel.

3. Jacket: Sheet metal, with screw-fastened closures and powder-coated protective finish.
4. Mounting base to secure boiler to concrete base.
5. Control Compartment Enclosure: NEMA 250, Type 1A.

F. Barometric Damper: Galvanized-steel assembly with flue-gas thermometer. Boilers shall be capable of operating with full turndown on combined flues where required by design.

2.02 ELECTRICAL POWER

A. All conductors shall be Copper. Insulation shall comply with NEMA WC 70, type THHN-THWN. Control cable for class 1 remote control and signal circuits: Copper conductor, 600 volt insulation, rated at 60 deg C, individual conductors twisted together, shielded, and covered with a PVC jacket. All splices shall be factory-fabricated connectors and splices of size, ampacity rating, material, type, and class for application and service required. Minimum wire size shall be based on the over-current protection device and as governed by the NEC.

B. House in NEMA 250, Type 1 enclosure.

C. Wiring shall be numbered and color-coded to match wiring diagram. All wire color coding shall be factory-applied. Field-applied color coding (“phase tape”) is prohibited.

D. Install factory wiring outside of an enclosure in EMT complying with ANSI C80.3 and UL797.

E. Field power interface shall be to fused disconnect switch or circuit breaker.

F. Provide branch power circuit to each motor and to controls with disconnect switch or circuit breaker.

G. Provide each motor with overcurrent protection.

2.03 SOURCE QUALITY CONTROL

A. Test and inspect factory-assembled boilers, before shipping, according to ASME Boiler and Pressure Vessel Code.

B. Burner and Hydrostatic Test: Factory or field adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency. Perform hydrostatic test in factory and then again after boiler is assembled and set.

C. Allow Owner access to source quality-control testing of boilers. Notify DEN Project Manager 14 days in advance of testing.

PART 3 EXECUTION

3.01 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

B. Tests and Inspections:

1. Perform installation and startup checks according to manufacturer's written instructions.
2. Leak Test: Hydrostatic test. Repair leaks and retest until no leaks exist.
3. Operational Test: Start units to confirm proper motor rotation and unit operation. Adjust air-fuel ratio and combustion.
4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
    a. Burner Test: Adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency.
    b. Check and adjust initial operating set points and high- and low-limit safety set points of fuel supply, water level, and water temperature.

c. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

C. Remove and replace malfunctioning units and retest.

D. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two (2) visits to Project during other than normal occupancy hours for this purpose.

E. Performance Tests:

1. Provide a factory-authorized service representative to inspect component assemblies and equipment installations, including connections, and to conduct performance testing.
2. Boilers shall comply with performance requirements indicated, as determined by field performance tests. Adjust, modify, or replace equipment in order to comply.
3. Perform field performance tests to determine the capacity and efficiency of the boilers.
   a. For dual-fuel boilers, perform tests for each fuel.
   b. Test for full capacity.
   c. Test for boiler efficiency at low fire 20, 40, 60, 80, 100, 80, 60, 40 and 20 percent of full capacity. Determine efficiency at each test point.
4. Repeat tests until results comply with requirements indicated.
5. Provide analysis equipment required to determine performance.
6. Provide temporary equipment and system modifications necessary to dissipate the heat produced during tests if building systems are not adequate.
7. Notify DEN Project Manager in advance of test dates.
8. Document test results in a report and submit to DEN Project Manager.

3.02 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain boilers. Video the training sessions.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 235239: Fire-Tube Boilers

PART 1 GENERAL

Engineer to use the Design Summary section below for evaluation and selection of equipment used in the design.

1.01 DESIGN SUMMARY

A. Evaluation: Boilers will be evaluated on a “best value” basis considering the following factors.

1. Manufacturer’s guaranteed Output Capacity within the space available.
2. Emissions.
3. Life Cycle Cost (LCC) performance.
   a. Total Installed Cost.
   b. Gas consumption at project loads and elevation deration.
   c. Electrical consumption (including fan).
   d. Operation and maintenance costs.
4. Maintainability of boiler layout.
5. Compliance with specification requirements

6. Lead Time to meet or beat 24 weeks lead time from date of approved shop drawings with no more than 2 weeks between award of project and delivery of shop drawings. This requirement to be verified with DEN PM.

B. DEN does not use steam for heating systems.

C. For multiple boiler systems, proposed boilers shall be identical including all ancillary components and equipment.

D. Boiler total weight including housekeeping pad shall impart no more than 250 lb/sqft while operating if located in the lower level of the CUP. Match existing flue and piping connection points to the greatest extent possible.

E. Design to meet scheduled/specified conditions and for normal operation at elevation of 5,400 ft above sea level.

F. Factory assembled and tested. Partial assembly allowed only as required for access to boiler room. If partial field assembly is required, submit request to DEN Mechanical Engineer for approval.

G. Trim, and accessories for fire-tube boilers with the following configurations, burners, and outputs:

1. Burner- Combination natural gas and Jet-A fuel burner.
   a. The burner shall be Low NOx emissions, 15 ppm or less when firing on natural gas. Manufacturer shall guarantee output capacity per scheduled contract documents and turndown capacity with NOx compliant operation. Manufacturer is responsible for field verification of guarantees listed above.
   b. Burner shall be fully modulating, minimum 6.5:1 turndown ratio with the following certifications and features:
      1. Remote/automatic fuel switchover between gas and fuel oil.
      2. Burner and Orifices: Stainless steel or Cast iron, for natural gas and Jet-A.
      3. Jet-A fuel supply: Control devices and full-modulating control sequence shall comply with requirements in ASME CSD-1.
      4. Gas Train: Control devices and full-modulation control sequence shall comply with requirements in AGA and ASME CSD-1.
      5. Pilot: Intermittent-electric-spark pilot ignition with 100 percent main-valve and pilot-safety shutoff with electronic supervision of burner flame.
      6. Welded construction with multivane, stainless-steel flame-retention diffuser for natural gas. Mount burner on hinged access door to permit access to combustion chamber.
      7. Burner and boiler assembly shall have self-contained ability to atomize Jet Fuel-A for operation, by compressed air or other required means.
2. Blower: Forward-curved centrifugal fan integral to burner, directly driven by motor; with adjustable, dual-blade damper assembly and locking quadrant to set air-fuel ratio.
   a. Motors: Indicated, large enough so driven load will not require motor to operate in service factor range above 1.0. Motor shall be sized to drive fan at full speed at minimum ambient temperature. Provide inverter duty rated motors.
3. Trim:
   a. Pressure and Temperature Gage: Minimum 3-1/2-inch diameter, combination water-pressure and-temperature gage. Gages shall have operating-pressure and -temperature ranges so normal operating range is about 50 percent of full range.
   b. Manual Boiler Air Vent is preferred.
   c. Minimum NPS 1 hose-end gate valve drain.
   d. ASME rated safety relief valve(s) rated for 150 PSI relief setting.
4. Controls:

a. Provide listed cable management products, such as cable tray, cable ties, tie mounts, and accessories as required for routing of wiring within enclosures. All wiring within enclosures shall be managed and neatly arranged.

b. Boiler operating controls shall include the following devices and features per Boiler:

1. Control transformer.
2. Set points shall be adjustable.
3. Hand, off, automatic control to the local boiler.
4. Interface Screen at the boiler control panel shall be minimum 10” in size (diagonal measurement).

c. Burner Operating Controls: To maintain safe operating conditions, burner safety controls limit burner operation.

1. High Cutoff: Automatic reset stops burner if operating conditions rise above maximum boiler design temperature or pressure.
2. Low-Water Cutoff Switch: Electronic probe shall prevent burner operation on low water. Cutoff switch shall be automatic-reset type. Piping assembly shall not be a dead leg where air may accumulate and cause nuisance trips.
3. Blocked Vent Safety Switch: Manual-reset switch factory mounted on draft diverter.
4. Rollout Safety Switch: Factory mounted on boiler combustion chamber.
5. Audible Alarm: Factory mounted on control panel with silence switch; shall sound alarm for above conditions.
6. Self-actuating flue damper controls system capable of operating two boilers on a single flue exhaust chimney.
7. Burner high water output temperature trip setting shall be no lower than 250 degrees F. CUP Heating Water system operates at 230 degrees F supply water temperature.

5. Building Automation System Interface: Factory install hardware and software to enable building automation system to monitor, control, and display boiler status and alarms.

a. Monitoring: On/off status, firing rate, common trouble alarm and low water level alarm.

b. Control: On/off operation, hot water supply temperature set-point adjustment.

c. A communication interface with building automation system shall enable building automation system operator to remotely control and monitor the boiler from an operator workstation. Control features available, and monitoring points displayed, locally at boiler control panel shall be available through building automation system.

d. Provide hardwired remote-control capability from BAS to each boiler panel, each boiler shall have dedicated control panel, for on/off and supply water setpoint control.

e. Provide each boiler with necessary hardware for BACnet MSTP output communications protocol.

6. Single-Point Field Power Connection: Factory-installed and-wired switches, motor controllers, transformers, and other electrical devices necessary shall provide a single-point field power connection to boiler.

1.02 ACTION SUBMITTALS

A. Product Data: Provide data indicating general assembly, components, controls, safety controls, and wiring diagrams with electrical characteristics and connection requirements, and service connections.

1. Include performance data, operating characteristics, furnished specialties, and accessories.
2. Include data substantiating that materials comply with requirements.

B. Shop Drawings: For boilers, boiler trim, and accessories. Include plans, elevations, sections, details, shipped loose components, and attachments to other work.

1. Wiring Diagrams: Power, signal, and control wiring.

2. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
3. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
4. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

1.03 INFORMATIONAL SUBMITTALS

A. Information in this section is required to be submitted at least 2 weeks prior to shipping.

1. Source quality-control test reports.
2. Manufacturer's Certificate: Certify that units meet or exceed specified requirements.
3. Field quality-control test reports. Indicate condition of equipment after start-up including control settings and performance chart of control system.
4. Test Reports: Indicate specified performance and efficiency is met or exceeded. Provide factory combustion test data for substantially identical unit that includes boiler firing rate, overfire draft, gas flow rate, heat input, burner manifold gas pressure, percent carbon monoxide (CO), percent oxygen (O), percent excess air, flue gas temperature at outlet, ambient temperature, net stack temperature, percent stack loss, percent combustion efficiency, and heat output.

1.04 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For boilers, components, and accessories to include in emergency, operation, and maintenance manuals.

1. Include manufacturer’s descriptive literature, operating instructions, cleaning procedures, replacement parts list, and maintenance and repair data.
2. As-Built Plans: Submit complete as-built plans of all Work, including interface with other Work.

1.05 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace heat exchangers damaged by thermal shock and vent dampers of boilers that fail in materials or workmanship within specified warranty period. This full warranty shall include both repair or replacement parts as needed, and labor to complete said warranty service.

1. Warranty Period for Heat Exchangers: Minimum twenty (20) years from date of Substantial Completion.

B. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace drums, tubes, headers, cabinets, atmospheric gas & fuel burners, control systems, and pressure vessels of boilers that fail in materials or workmanship within specified warranty period. This full warranty shall include both repair or replacement parts as needed, and labor to complete said warranty service.

1. Warranty Period for Tubes, Headers, Cabinets, Burner, and Control System: Minimum five (5) years from date of Substantial Completion.
2. Warranty Period for Refractory: Minimum ten (10) years from date of Substantial Completion.
3. Warranty Period for Vent Dampers: Minimum Five (5) years from date of Substantial Completion.

C. Coordinate substantial completion milestones with DEN operations for warranty period validation.

PART 2 PRODUCTS

2.01 ELECTRICAL POWER

A. All conductors shall be Copper. Insulation shall comply with NEMA WC 70, type THHN-THWN. Control cable for class 1 remote control and signal circuits: Copper conductor, 600 volt insulation, rated at 60 deg C, individual conductors twisted together, shielded, and covered with a PVC jacket. All splices shall be factory-fabricated connectors and splices of size, ampacity rating, material, type, and class for application and service required. Minimum wire size shall be based on the over-current protection device and as governed by the NEC.

B. House in NEMA 250, Type 1 enclosure.

C. Wiring shall be numbered and color-coded to match wiring diagram. All wire color coding shall be factory-applied. Field-applied color coding ("phase tape") is prohibited.

D. Install factory wiring outside of an enclosure in EMT complying with ANSI C80.3 and UL797.

E. Field power interface shall be to fused disconnect switch or circuit breaker.

F. Provide branch power circuit to each motor and to controls with disconnect switch or circuit breaker.

G. Provide each motor with overcurrent protection.

2.02 SOURCE QUALITY CONTROL

A. Test and inspect factory-assembled boilers, before shipping, according to ASME Boiler and Pressure Vessel Code.

B. Burner and Hydrostatic Test: Factory or field adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency. Perform hydrostatic test in factory and then again after boiler is assembled and set.

C. Allow Owner access to source quality-control testing of boilers. Notify DEN Project Manager 14 days in advance of testing.

PART 3 EXECUTION

3.01 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

B. Tests and Inspections:

1. Perform installation and startup checks according to manufacturer's written instructions.
2. Leak Test: Hydrostatic test. Repair leaks and retest until no leaks exist.
3. Operational Test: Start units to confirm proper motor rotation and unit operation. Adjust air-fuel ratio and combustion.
4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
    a. Burner Test: Adjust burner to eliminate excess oxygen, carbon dioxide, oxides of nitrogen emissions, and carbon monoxide in flue gas and to achieve combustion efficiency.
    b. Check and adjust initial operating set points and high- and low-limit safety set points of fuel supply, water level, and water temperature.
    c. Set field-adjustable switches and circuit-breaker trip ranges as indicated.

C. Remove and replace malfunctioning units and retest.

D. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two (2) visits to Project during other than normal occupancy hours for this purpose.

E. Performance Tests:

1. Provide a factory-authorized service representative to inspect component assemblies and equipment installations, including connections, and to conduct performance testing.
2. Boilers shall comply with performance requirements indicated, as determined by field performance tests. Adjust, modify, or replace equipment in order to comply.
3. Perform field performance tests to determine the capacity and efficiency of the boilers.
   a. For dual-fuel boilers, perform tests for each fuel.
   b. Test for full capacity.
   c. Test for boiler efficiency at low fire 20, 40, 60, 80, 100, 80, 60, 40 and 20 percent of full capacity. Determine efficiency at each test point.
4. Repeat tests until results comply with requirements indicated.
5. Provide analysis equipment required to determine performance.
6. Provide temporary equipment and system modifications necessary to dissipate the heat produced during tests if building systems are not adequate.
7. Notify DEN Project Manager in advance of test dates.
8. Document test results in a report and submit to DEN Project Manager.

3.02 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain boilers. Video the training sessions.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 235313: Boiler Feedwater Pumps

DEN does not use steam for heating.

Section 235316: Deaerators

DEN does not use steam for heating.

Section 235513.16: Gas-Fired Duct Heaters

PART 1 GENERAL

1.01 INFORMATIONAL SUBMITTALS

Coordinate requirements for coordination drawings with DEN Project Manager.

A. Coordination Drawings: Plans, elevations, and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Structural members to which equipment will be attached.
2. Items penetrating roof and the following:
   a. Duct, vent, and gas piping rough-ins and connections.

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 PIPING CONNECTIONS

A. Where installing piping adjacent to gas-fired duct heaters, allow space for service and maintenance.

Section 235700: Heat Exchangers For HVAC

PART 1 GENERAL

1.01 INFORMATIONAL SUBMITTALS

Coordinate requirements for coordination drawings with DEN Project Manager.

A. Coordination Drawings: For situations where limited space necessitates maximum utilization for efficient installation of different components or if coordination is required for installation of products and materials by separate installers. Preparation of coordination drawings requires the participation of each trade involved in installations within the limited space.

1. Coordinate requirements for coordination drawings with DEN Project Manager.
2. Coordination Drawings: Equipment room, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
   a. Tube-removal space.
   b. Structural members to which heat exchangers will be attached.

PART 2 PRODUCTS

PART 3 EXECUTION

Section 236200: Packaged Compressor and Condenser Units

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Shop Drawings: For compressor and condenser units. Include plans, elevations, sections, details, and attachments to other work.

1. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
   a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
   b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

1.02 EXTRA MATERIALS

Extra stock materials may not be allowed on publicly funded projects. Coordinate extra stock submittal requirements with DEN Project Manager.

A. Provide two (2) sets of fan belts

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 CONNECTIONS

A. Where installing piping adjacent to equipment, allow space for service and maintenance of equipment.

3.02 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain compressor and condenser units.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 236313: Air-Cooled Refrigerant Condensers

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Shop Drawings: For compressor and condenser units. Include plans, elevations, sections, details, and attachments to other work.

1. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:

a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.

b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

1.02 EXTRA MATERIALS

Extra stock materials may not be allowed on publicly funded projects. Coordinate extra stock submittal requirements with DEN Project Manager.

A. Provide two (2) sets of fan belts

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 CONNECTIONS

A. Where installing piping adjacent to equipment, allow space for service and maintenance of equipment.

3.02 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain compressor and condenser units.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 236333: Evaporative Refrigerant Condensers

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include rated capacities, pressure drop, fan performance data, installation instructions, furnished specialties, and accessories.

1. Maximum flow rate.
2. Minimum flow rate.
3. Drift loss as percent of design flow rate.
4. Volume of water in suspension for purposes of sizing a remote storage tank (if needed).
5. Sound power levels in eight octave bands for operation with fans off, fans at minimum speed, and fans at design speed.
6. Performance curves for the following:

a. Varying entering-water temperatures from design to minimum.

b. Varying ambient wet-bulb temperatures from design to minimum.

c. Varying water flow rates from design to minimum.

d. Varying fan operation (off, minimum speed, and design speed).

7. Fan airflow, brake horsepower, and drive losses.

8. Pump flow rate, head, brake horsepower, and efficiency.

9. Motor amperage, efficiency, and power factor at 100, 75, 50, and 25 percent of nameplate horsepower.

10. Electrical power requirements for each evaporative refrigerant condenser component requiring power.

11. Include data substantiating that materials comply with requirements.

B. Shop Drawings: For evaporative refrigerant condensers. Include plans, elevations, sections, details, and attachments to other work.

1. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:

a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.

b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

1.02 INFORMATIONAL SUBMITTALS

Coordinate requirements for coordination drawings with DEN Project Manager.

A. Coordination Drawings: Plans, elevations, and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved.

1. Structural supports.

2. Piping and wiring roughing-in requirements (determine spaces reserved for electrical equipment).

3. Access requirements for service and maintenance.

1.03 EXTRA MATERIALS

Extra stock materials may not be allowed on publicly funded projects. Coordinate extra stock submittal requirements with DEN Project Manager.

a. Provide two (2) sets of fan belts.

1.04 WARRANTY

Coordinate warranty requirements with DEN Project Manager.

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of evaporative refrigerant condensers that fail in materials or workmanship within specified warranty period.

1. Failures include, but are not limited to, the following:

a. Fan, motor, drive shaft, bearings, and motor supports.

b. Tube bundle.

c. External-circuit circulating pump.

2. Warranty Period: Minimum five (5) years from date of Substantial Completion.

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 STARTUP SERVICE

A. Engage a factory-authorized service representative to assist Contractor and perform startup service.

3.02 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain evaporative refrigerant condensers.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 236416: Centrifugal Water Chillers

PART 1 GENERAL

1.01 PERFORMANCE REQUIREMENTS

A. Design Data:

1. Entering Condenser Water Temperature – 71 deg F
2. Entering Evaporator Water Temperature – 56 deg F
3. Leaving Evaporator Water Temperature – 40 deg F

B. Condenser-Fluid Temperature Performance:

1. Startup Condenser-Fluid Temperature: Chiller shall be capable of starting with an entering condenser-fluid temperature of 55 deg F and providing stable operation until the system temperature is elevated to the minimum operating entering condenser-fluid temperature.
2. Minimum Operating Condenser-Fluid Temperature: Chiller shall be capable of continuous operation over the entire capacity range indicated with an entering condenser-fluid temperature of 55 deg F.
3. Make factory modifications to standard chiller design if necessary to comply with performance indicated.
4. Site Altitude: Chiller shall be suitable for altitude at which installed without affecting performance indicated. Make adjustments to affected chiller components to account for site altitude of 5400 feet above sea level.

1.02 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include refrigerant, rated capacities, operating characteristics, furnished specialties, and accessories.

1. Performance at AHRI standard conditions and at conditions indicated.
2. Performance at AHRI standard unloading conditions.
3. Minimum evaporator flow rate.
4. Refrigerant capacity of chiller.
5. Oil capacity of chiller.
6. Fluid capacity of evaporator and condenser.
7. Characteristics of safety relief devices.
8. Minimum entering condenser-fluid temperature.
9. Performance at varying capacities with constant design condenser-fluid temperature. Repeat performance at varying capacities for different condenser-fluid temperatures from design to minimum in 5 deg F increments.
10. Include data substantiating that materials comply with requirements

B. Shop Drawings: Include plans, elevations, sections, details, and attachments to other work.

1. Detail equipment assemblies and indicate dimensions, weights, load distribution, required clearances, method of field assembly, components, and location and size of each field connection.
2. Wiring Diagrams: For power, signal, and control wiring.
3. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
   a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
   b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

1.03 INFORMATIONAL SUBMITTALS

Coordinate requirements for coordination drawings with DEN Project Manager.

A. Coordination Drawings: Floor plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Structural supports.
2. Piping roughing-in requirements.
3. Wiring roughing-in requirements, including spaces reserved for electrical equipment.
4. Access requirements, including working clearances for mechanical controls and electrical equipment, and tube pull and service clearances

1.04 MAINTENANCE MATERIALS

A. Provide canister(s) with one spare charge of refrigerant.

1.05 WARRANTY

Coordinate warranty requirements with DEN Project Manager.

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of chillers that fail in materials or workmanship within specified warranty period.

1. Extended warranties include, but are not limited to, the following:
   a. Complete chiller including refrigerant and oil charge.
   b. Parts and labor.
   c. Loss of refrigerant charge for any reason.
2. Warranty Period: Minimum two (2) years from date of Substantial Completion.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Carrier Corporation; a unit of United Technologies Corp.
2. Trane.
3. YORK; a Johnson Controls company.
4. or approved equal.

2.02 ELECTRICAL

A. Factory installed and wired, and functionally tested at factory before shipment.

B. Single-point, field-power connection to fused disconnect switch. Minimum withstand rating shall be as required by electrical power distribution system, but not less than 65,000 A.

2.03 ACCESSORIES

Coordinate requirement with DEN Project Manager.

A. Tool Kit: Chiller manufacturer shall assemble a tool kit specially designed for use in serving the chiller(s) furnished. Include special tools required to service chiller components not readily available to Owner service personnel in performing routine maintenance. Place tools in a lockable case with hinged cover. Provide a list of each tool furnished and attach the list to underside of case cover.

PART 3 EXECUTION

3.01 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain chillers. Video record the training sessions.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 236500: Cooling Towers

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Product Data: For each type of product indicated. Include rated capacities, dimensions, weights and point loadings, required clearances, electrical requirements and wiring diagrams, location and size of field connections, pressure drop, fan performance data, rating curves with selected points indicated, furnished specialties, and accessories. Submit schematic indicating capacity controls.

1. Maximum flow rate.
2. Minimum flow rate.
3. Drift loss as percent of design flow rate
4. Volume of water in suspension for purposes of sizing a remote storage tank (if needed).
5. Sound power levels in eight octave bands for operation with fans off, fans at minimum, and design speed, at a distance of 10 feet from the tower on all sides and above.
6. Performance curves for the following:
   a. Varying entering-water temperatures from design to minimum.
   b. Varying ambient wet-bulb temperatures from design to minimum.
   c. Varying water flow rates from design to minimum.
   d. Varying fan operation (off, minimum, and design speed).
7. Fan airflow, brake horsepower, and drive losses.
8. Pump flow rate, head, brake horsepower, and efficiency.
9. Motor amperage, efficiency, and power factor at 100, 75, 50, and 25 percent of nameplate horsepower.
10. Electrical power requirements for each cooling tower component requiring power.
11. Include data substantiating that materials comply with requirements.

B. Shop Drawings: Complete set of manufacturer's prints of cooling tower assemblies, control panels, sections and elevations, and unit isolation. Include the following:

1. Assembled unit dimensions.

2. Weight and load distribution.
3. Required clearances for maintenance and operation.
4. Sizes and locations of piping and wiring connections.
5. Wiring Diagrams: For power, signal, and control wiring.
6. Show proposed physical layout of equipment relative to the space in which it is to be installed, to demonstrate:
   a. Coordination of piping, duct, venting and electrical connections (as applicable) in relationship to adjacent work and building elements.
   b. Acceptable clearances for servicing and maintaining equipment to be installed, including adjacent equipment not specified by this Section.

1.02 INFORMATIONAL SUBMITTALS

Coordinate requirements for coordination drawings with DEN Project Manager.

A. Coordination Drawings: Floor plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:

1. Structural supports.
2. Piping roughing-in requirements.
3. Wiring roughing-in requirements, including spaces reserved for electrical equipment.
4. Access requirements, including working clearances for mechanical controls and electrical equipment, and tube pull and service clearances.

1.03 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For each cooling tower to include in emergency, operation, and maintenance manuals.

1.04 EXTRA MATERIALS

Extra stock materials may not be allowed on publicly funded projects. Coordinate extra stock submittal requirements with DEN Project Manager.

A. Provide two (2) sets of matched fan belts.

B. Provide two (2) spray nozzles for each cell.

C. Provide one (1) valve seat for each make-up or control valve.

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 FIELD QUALITY CONTROL

A. Perform tests and inspections.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to assist Contractor and inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

3.02 STARTUP SERVICE

A. Engage a factory-authorized service representative to assist Contractor and perform startup service.

3.03 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain cooling towers.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 237423.13: Packaged, Direct-Fired, Outdoor, Heating-Only Makeup-Air Units

PART 1 GENERAL

1.01 INFORMATIONAL SUBMITTALS

Coordinate requirements for coordination drawings with DEN Project Manager.

A. Coordination Drawings: Plans, elevations, and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Structural members to which equipment will be attached.
2. Items penetrating roof and the following:
   a. Duct, vent, and gas piping rough-ins and connections.

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 PIPING CONNECTIONS

A. Where installing piping adjacent to gas-fired equipment, allow space for service and maintenance.

Section 237423.16: Packaged, Indirect-Fired, Outdoor, Heating-Only Makeup-Air Units

PART 1 GENERAL

1.01 INFORMATIONAL SUBMITTALS

Coordinate requirements for coordination drawings with DEN Project Manager.

A. Coordination Drawings: Plans, elevations, and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Structural members to which equipment will be attached.
2. Items penetrating roof and the following:
   a. Duct, vent, and gas piping rough-ins and connections.

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 PIPING CONNECTIONS

A. Where installing piping adjacent to gas-fired equipment, allow space for service and maintenance.

End of Chapter

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Appendix A – Controls Points Abbreviations

Below is a list of DEN approved standard controls points abbreviations. Non-standard abbreviations must be approved in writing by DEN Mechanical Engineer.

Appendix A - Control Points Abbreviations

Identifiers	Description
AF-OFST	Return Airflow Offset from Total Supply
AHU-MODE	AHU Mode
BYPD-C	Bypass Damper Command
CHWE-F	Chilled Water Entering Flow
CHWE-T	Chilled Water Entering Temp
CHWL-T	Chilled Water Leaving Temp
CHWR-T	Chilled Water Return Temperature
CHWS-T	Chilled Water Supply Temperature
CLG-FB	Cooling Valve Feedback
CLG-M	Cooling Mode
CLG-O	Cooling Output
CLG-O-BTU	Cooling Valve BTU
CLG-O-FLOW	Cooling Flow
CLG-VLV-FAIL	Chilled Water Valve Failure
CO2-RESET	DCV Reset Enable
CW-ALM-DLY	Chilled Water Coil Alarm Time Delay
CW-ALM-SP	Chilled Water Coil Alarm Threshold
DA-F	Discharge Air Flow
DA-P	Discharge Air Static Pressure
DAP-EFF-SP	Effective Discharge Air Press Setpoint
DAP-IGN	DA Pressure Ignore Requests
DAP-ITSP	Initial Discharge Air Pressure Setpoint
DAP-MAX-SP	Maximum DA Pressure Setpoint
DAP-MIN-SP	Minimum DA Pressure Setpoint
DAP-REQS	DA Pressure Requests
DAP-RES	Setpoint Response DA Pressure Reset
DAP-RES-MAX	Setpoint Maximum Response DA Reset
DAPR-MODE	DA Pressure Reset Mode

Appendix A - Control Points Abbreviations (Continued)

Identifiers	Description
DAP-STRT-RP	Static Pressure Setpoint Ramp Time
DAP-T-D	Time Delay DA Pressure Reset
DAP-T-INT	Time Interval DA Pressure Reset
DAP-TRIM	Setpoint Trim DA Pressure Reset
DA-T	Discharge Air Temperature
DA-T-ALM	Discharge Air Temp Setpoint Alarm
DAT-ALM-DB	AHU DAT Alarm Deadband
DAT-ALM-DLY	AHU DAT Alarm Delay Time
DAT-ALM-TM	AHU DAT Alarm Time Threshold
DAT-EFF-SP	Effective Discharge Air Temp Setpoint
DAT-HI-OAT	High OAT for DAT Reset
DAT-IGN	DAT Ignore Requests
DAT-ITSP	Initial Discharge Air Temp Setpoint
DAT-LO-OAT	Low OAT for DAT Reset
DAT-MAX-SP	Maximum DA Temp Setpoint
DAT-MIN-SP	Minimum DA Temp Setpoint
DAT-MRN-CLG	Morning Pre-Cool Discharge Temp Setpoint
DAT-MRN-WRM	Morning Warmup Discharge Temp Setpoint
DAT-REQS	DA Temperature Requests
DAT-RES	Setpoint Response DA Temp Reset
DAT-RES-MAX	Setpoint Maximum Response DA Reset
DATR-MODE	DA Temperature Reset Mode
DAT-STBK	Unoccupied Setback Disch Temp Setpoint
DAT-STUP	Unoccupied Setup Discharge Temp Setpoint
DAT-T-D	Time Delay DA Temp Reset
DAT-T-INT	Time Interval DA Temp Reset
DAT-TRIM	Setpoint Trim DA Temp Reset
DA-VP	Discharge Air Velocity Pressure
DESIGN-DA-F	Design Discharge Flow
DHC-FB	Defrost Heating Valve Feedback
DHCL-T	Defrost Leaving Temp

Appendix A - Control Points Abbreviations (Continued)

Identifiers	Description
DHC-O	Defrost Heating Output
DHWE-F	Defrost Hot Water Entering Flow
DHWE-T	Defrost Hot Water Entering Temp
DHWL-T	Defrost Hot Water Leaving Temp
DHWT-SP	Defrost Temp Setpoint
EAD-FB	Exhaust Air Damper Feedback
EAD-O	Exhaust Air Damper Output
EA-EW-T	Exhaust Air Entering Wheel Temp
EA-F	Exhaust Air Flow
EA-FILT-DP	EA Filter Diff Pressure
EA-LW-T	Exhaust Air Leaving Wheel Temp
ECON-DB	Economizer Deadband
ECON-ENA	Economizer Mode Enable
EF-AF	Exhaust Fan Associated with AHU Airflow
EF-C	Exhaust Fan Command
EFF-CDAT-SP	Effective Cooling DAT Setpoint
EFF-HDAT-SP	Effective Heating DAT Setpoint
EFF-OA-T	Effective Outside Air Temperature
EF-HP	Exhaust Fan High Pressure
EF-HSP	EF High Static Pressure Alarm
EF-O	Exhaust Fan Output
EF-S	Exhaust Fan Status
EF-VP	Exhaust Fan Velocity Pressure
ERW-C	Energy Recovery Wheel Command
ERW-O	Energy Recovery Wheel Output
ERW-S	Energy Recovery Wheel Status
ERW-ALM	Energy Recovery Wheel Alarm
FLTR-DP	Filter Differential Pressure
FIRE-ALM	Fire Alarm
FLTR-WRN	Filter Warning
FLTR-WRN-SP	Filter Warning Setpoint

Appendix A - Control Points Abbreviations (Continued)

Identifiers	Description
HI-DAT-ALM	High Discharge Temp Alarm
HI-DAT-SP	High Discharge Setpoint
HP-ALM	DA High Duct Pressure Alarm
HTG-EN	Global Heating Enable
HTG-M	Heating Mode
HW-ALM-DLY	Hot water Coil Alarm Time Delay
HW-ALM-SP	Hot water Coil Alarm Threshold
LDAT-ALM	Low Discharge Air Temp Alarm
LDAT-SP	Low DA Temp Setpoint
LTA-R	Low Temp Alarm Reset
LT-SP	Low Limit Setpoint
LP-ALM	Low Duct Pressure Alarm
LT-ALM	Low Temperature Alarm
LT-S1-ALM	Low Limit Stage 1 Alarm
LT-S2-ALM	Low Limit Stage 2 Alarm
MA-LT-ALM	Mixed Air Low Limit Alarm
MA-T	Mixed Air Temperature
MAT-LL	Mixed Air Temp Low Limit
MAT-LL-DLY	Mixed Air Temp Low Limit Release Delay
MECH-CLG-DLY	Mechanical Cooling Time Delay
MOA-CO2RSTA	CO2 Low Range
MOA-CO2RSTB	CO2 High Range
MPC-END	Morning Pre-Cool End Month
MPC-OAT	Morning Pre-Cool OAT Enable Temp
MPC-STPT	Morning Pre-Cool Space Setpoint
MPC-STRT	Morning Pre-Cool Start Month
MRN-CLG	Morning Cool-down Mode
MRN-WRM	Morning Warm-up Mode
OAD-FB	Outdoor Air Damper Feedback
OAD-O	Outdoor Air Damper Output
OA-F	Outside Air Flow

Appendix A - Control Points Abbreviations (Continued)

Identifiers	Description
OA-FILT-DP	OA Filter Diff Pressure
OA-F-SP	Outside Air Flow Setpoint
OAG-DAT-SP	OAT Greater DA Temp Setpoint
OAL-DAT-SP	OAT Less DA Temp Setpoint
OA-T	Global Outside Temperature
OCC-C	Occupied Mode
OCC-M	Occupied Mode
PFILT-DP-ALM-DLY	PreFilter Alarm Delay
PH-FB	Preheat Valve Feedback
PH-O	Preheat Output
PH-O-BTU	Preheat Valve BTU
PH-O-F	Preheat Flow
PH-T	Preheat Temp
PH-VLV-FAIL	Hot Water Valve Failure
PHW-F	Preheat Water Entering Flow
PHWR-T	Hot Water Return Temperature
PHWS-T	Hot Water Supply Temperature
PID-TMP-DB	PID Deadband Heating Econ Cooling
PWR-FAIL-DLY	Power Failure Restart Delay Time
PWR-FAIL-INT-UNIT-DLY	Power Fail Interstage Unit Delay
RAD-FB	Return Air Damper Feedback
RAD-O	Return Air Damper Output
RA-F	Return Air Flow
RAF-AF-SP	Return Airflow Setpoint
RAF-C	Return Air Fan Command
RAF-MM-ALM	Return Fan Mismatch Alarm
RAF-O	Return Air Fan Output
RAF-S	Return Air Fan Status
RA-H	Return Air Humidity
RA-SD-ALM	Return Air Smoke Detector Alarm

Appendix A - Control Points Abbreviations (Continued)

Identifiers	Description
RA-T	Return Air Temperature
RA-T	Return Air Temp
SA-F	Supply Air Flow
SA-SD-ALM	Supply Air Smoke Detector Alarm
SD-CMD	Shutdown Command
SF-C	Supply Fan Command
SF-MM-ALM	Supply Fan Mismatch Alarm
SF-O	Supply Fan Output
SF-S	Supply Fan Status
SYS-OFF	System Off Mode
SYS-RESET	System Reset
T-MIN	DAT Minimum at High OAT
TUNING-RESET	Tuning Reset
UNIT-CNT	Device No for Interstage Unit Delay
UNIT-RESET	Unit Reset
UNOCC-CLG-DB	Unoccupied Cooling Deadband
UNOCC-CLG-SP	Unoccupied Cooling Setpoint
UNOCC-HTG-DB	Unoccupied Heating Deadband
UNOCC-HTG-SP	Unoccupied Heating Setpoint
UNOCC-STATE	Unoccupied State
UNOCC-STBK	Unoccupied Setback Mode
UNOCC-STUP	Unoccupied Setup Mode
V_OT	Minimum Outside Air Setpoint -Non-DCV
V_OT-MIN	DCV Minimum Outside Air Setpoint
VAV-CO2-MAX	Maximum Zone CO2
VAV-T-AVG	VAVs Temp Average
VAV-T-MAX	VAVs Temp Maximum
VAV-T-MIN	VAVs Temp Minimum

Table 13-3: Appendix A - VAV Points Abbreviations

Identifier	Description
AHU-SA-T	Supply Air Temperature
AHU-SF-S	AHU Supply Air Fan Status
AUTOCAL-C	Autocalibrate
AVG-MAX-CALC-ZN-T	ZN-T FOR Maximum & Average Calculation
HTG-ENA	Global Heating Enable
CLG-C	Cooling Command
CLG-MAXFLOW	Cooling Max Flow
CLGOCC-MINFLOW	Occ Cooling Min Flow
CLG-REQ	Discharge Temperature Request
DA-T	Discharge Air Temperature
DATHTGMAX-SP	Discharge Air Setpoint Heating Max
DA-VP	Discharge Air Velocity Pressure
DPR-O	Supply Air Damper Output
EFFCLG-SP	Effective Cooling Setpoint
EFFDAT-SP	Effective Discharge Setpoint
EFFHTG-SP	Effective Heating Setpoint
EFF-OCC	Effective Occupancy
EFF-SETPOINT	Active Setpoint
HTG-C	Heating Command
HTG-MAXFLOW	Heating Max Flow
HTG-O	Heating Output
HTGOCC-MINFLOW	Occ Heating Min Airflow
HTGSTBY-SP	Standby Heating Setpoint
IMP-V	Importance Factor
IRH-C	IRH Command
MIN-CALC-ZN-T	ZN-T for Minimum Calculation
NET-OCC	Supervisor Occupancy
OCC-CLG-SP	Occupied Cooling Setpoint
OCC-HTG-SP	Occupied Heating Setpoint

Table 13-3: Appendix A - VAV Points Abbreviations

Identifier	Description
OCC-SCHEDULE	Occupancy Schedule
SA-F	Airflow Rate
SAFLOW-SP	Flow Setpoint
SF-C	Supply Fan Command
SF-S	Supply Fan Status
SYSTEM-MODE	System/Control Mode
UNITEN-ENA	Unit Enable
UNIT-S	Unit Status
UNNOC-CLG-SP	Unoccupied Cooling Setpoint
UNNOC-DB	Unoccupied Deadband
UNNOC-HTG-SP	Unoccupied Heating Setpoint
UNNOC-STATE	Unoccupied Status
VAV-IGN-CAL	VAV Box Ignore for Calculation
WC-ADJ	Setpoint Offset
WC-C	Warmup/Cooldown
ZN-T	Zone Temperature
VFD Points	
FAULT	Fault Status
HOA	Hand/Off/ Auto Status
SPD-FBK	Speed Feedback
AMPS	Amperage/ Motor Current
HZ	Hertz/ Frequency
kWh	Kilowatt Hours
HRS	Run Hours
S	Running/ Stopped Status
C	Start/ Stop Command
0	Output
ALM	Alarm
Floating Point Valves	
OPN-C	Open Command
OPN-S	Open Status

Table 13-3: Appendix A - VAV Points Abbreviations

Identifier	Description
CLO-C	Close Command
CLO-S	Close Status
Equipment Control	
C	On/ Off Command
S	On/Off Status
ALM	Alarm
ENA	Enable/ Disable
MS	Normal/Maintenance mode
DP	Differential Pressure
RT	Run Time
Hydronic Elements	
HWS-T	Heating Water Supply Temperature
HWR-T	Heating Water Return Temperature
HWS-F	Heating Water Supply Flow
HWR-F	Heating Water Return Flow
HWS-P	Heating Water Supply Pressure
HWR-P	Heating Water Return Pressure
CWS-T	Condenser Water Supply Temperature
CWR-T	Condenser Water Return Temperature
CWS-F	Condenser Water Supply Flow
CWR-F	Condenser Water Return Flow
CWS-P	Condenser Water Supply Pressure
CWR-P	Condenser Water Return Pressure
CHWS-T	Chilled Water Supply Temperature
CHWR-T	Chilled Water Return Temperature
CHWS-F	Chilled Water Supply Flow
CHWR-F	Chilled Water Return Flow
CHWS-P	Chilled Water Supply Pressure
CHWR-P	Chilled Water Return Pressure
GLWS-T	Glycol Supply Temperature
GLYR-T	Glycol Return Temperature‘

Table 13-3: Appendix A - VAV Points Abbreviations

Identifier	Description
GLYS-F	Glycol Supply Flow
GLYR-F	Glycol Return Flow
GLYS-P	Glycol Supply Pressure
GLYR-P	Glycol Return Pressure
DP	Differential Pressure

End of Appendix

Matrix A: DEN Concourse A West Expansion Concessions

DEN Concourse A West Expansion Concessions Matrix

Space		Plan Name					Mechanical									Plumbing								Electrical		
							Cooling Load				Cooking			Ventilation (CFM)		Domestic Cold Water		Domestic Hot Water		San. Sewer)	Grease Waste)	Vent	Gas			
Location	Category	Room Number	Plan Tag	Seating Internal for F & B Operation	Dumb Waiter Shaft	Floor Area	Allowance (SF/TON)	Total (Tons)	Chilled Water Flow Allowance (GPM)	Heating Hot Water Flow Allowance (GPM)	(Y/N)	Type: Gas, Elect, G/E	Grease Exhaust	Dishwasher Exhaust	Hood Makeup from Outside	Service	Size (IN.)	Service	Size (IN.)	Size (IN.)	Size (IN.)	Size (IN.)	Size (IN.)	Maximum Load (AMPS)	Design Load (AMPS)	Connect Supported (VOLTS)
Subcore 6W Concourse Level[1]	Food & Beverage	CCA_02_6W_020	Concessions Seating	Y	Y	4,681	300	15.6	N/A	N/A	N	N/A	N/A	N/A	N/A	CW, Metered Up from Apron	2	Tenant-provided Electric Water Heater in the Space		4	N/A	N/A	3	400	424	277/480,3PH
Subcore 6W Concourse Level[1]	Back of House	CCA_02_6W_CR51	Circulation	N/A	Y	354	500	0.7	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Subcore 6W Apron Level[2]	Kitchen	CCA_01_6W_014	Concessions Kitchen	N/A	Y	1,786	300	6.0	16.7	29.3	Y	G/E	8800	700	9,500	CW, Metered	2	Tenant-provided Electric Water Heater in the Space		4	4	3	By Tenant (2400 CFH Allowance)	100	85	277/480,3PH
Subcore 6W Apron Level[2]	Storage	CCA_01_6W_013	Concessions Loading/ Storage	N/A	N	1,162	1200	1.0	3	3.7	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	3	277/480,3PH
Subcore 6W Basement Level[3]	Storage	N/A	N/A	N/A	N	3,290	N/A	N/A	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	8	277/480,3PH
Holdroom 7W[1]	Travel & Convenience	CCA_02_7W_037	Concessions	TBD	N	1,468	1000	1.5	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	200	124	277/480,3PH
Subcore 9W Concourse Level[1]	Food & Beverage	CCA_02_9W_020	Concessions Seating	Y	Y	4,681	300	15.6	N/A	N/A	N	N/A	N/A	N/A	N/A	CW, Metered Up From Apron	2	Tenant-provided Electric Water Heater in the Space		4	N/A	3	N/A	400	424	277/480,3PH
Subcore 9W Concourse Level[1]	Back of House	CCA_02_9W_CR06	Circulation	N/A	Y	354	500	0.7	N/A	N/A	N	N/A	N/A	N/A	N/A	CW, Metered Up From Apron	2	Tenant-provided Electric Water Heater in the Space		4	N/A	3	N/A	100	89	277/480,3PH
Subcore 9W Apron Level[2]	Storage/ Future Kitchen	CCA_01_9W_025	Concessions Storage	N/A	Y	954	300	3.3	9.9	17.3	Y	G/E	5200	425	5,600	CW, Metered	2	Tenant-provided Electric Water Heater in the Space		4	4	3	By Tenant (2400 CFH Allowance)	100	47	277/480,3PH
Subcore 9W Apron Level[2]	Loading/ Storage	CCA_01_9W_008	Loading/ Storage	N/A	N	627	1200	0.5	1.5	1.9	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	1.1	277/480,3PH

DEN Concourse A West Expansion Concessions Matrix (Continued)

Space		Plan Name					Mechanical									Plumbing								Electrical		
Subcore 9W Basement Level[1]	Storage	N/A	N/A	N/A	N	2,936	N/A	N/A	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	7	277/ 480,3PH
Holdroom 10W [3]	Travel & Convenience	CCA_02_10W _050	Concessions	TBD	N	1,054	1000	1.1	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	58	277/ 480,3PH

Notes:

[1] If required natural gas is provided by XCEL Energy during Tenant Design. Space air conditioning is from the Concourse VAV Air Handling Systems.

[2] If required natural gas is provided by XCEL Energy during Tenant Design. Space air conditioning is from the Apron VAV Air Handling Systems.

[3] If required natural gas is provided by XCEL Energy during Tenant Design. No Air handling systems exist in the basement for conditioning Tenant spaces.

Matrix B: DEN CEP Concourse B West Expansion Concessions

DEN CEP Concourse B West Expansion Concessions Matrix

Space		Plan Name					Mechanical									Plumbing								Electrical		
							Cooling Load				Cooking			Ventilation (CFM)		Domestic Cold Water		Domestic Hot Water		San. Sewer)	Grease Waste)	Vent	Gas			
Location	Category	Room Number	Plan Tag	Seating Internal for F & B Operation	Dumb Waiter Shaft	Floor Area	Allowance (SF/TON)	Total (Tons)	Chilled Water Flow Allowance (GPM)	Heating Hot Water Flow Allowance (GPM)	(Y/N)	Type: Gas, Elect, G/E	Grease Exhaust	Dishwasher Exhaust	Hood Makeup from Outside	Service	Size (IN.)	Service	Size (IN.)	Size (IN.)	Size (IN.)	Size (IN.)	Size (IN.)	Maximum Load (AMPS)	Design Load (AMPS)	Connect Supported (VOLTS)
Holdroom 8W Concourse Level	Travel & Convenience	CCB_02_8W _010	Travel & Convenience	TBD	N	754	600	1.3	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	64	277/ 480,3PH
Subcore 9W Concourse Level	Food & Beverage	CCB_02_9W _015	Concessions	Y	Y	3,784	150	25.2	N/A	N/A	N	N/A	N/A	N/A	N/A	CW, Metered Up From Apron	2	Tenant-provided Electric Water Heater in the Space		4	N/A	3	N/A	400	312	277/ 480,3PH
Subcore 9W Concourse Level	Back of House	CCB_02_9W _CR14	Corridor	N/A	Y	544	N/A	N/A	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Subcore 9W Apron Level	Kitchen	CCB_01_9W _023	Concessions Storage	N/A	Y	1,484	300	4.9	21	33	Y	G/E	8,800	700	9,500	CW, Metered	2	Tenant-provided Electric Water Heater in the Space		4	4	3	By Tenant (2400 CFH Allowance)	100	71	277/ 480,3PH
Subcore 9W Apron Level	Storage	CCB_01_9W _020	Concessions Storage	N/A	N	1,031	N/A	N/A	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	50	277/ 480,3PH
Storage Apron Level	Storage	CCB_01_9W _022	Loading	N/A	N	571	N/A	N/A	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	64	277/ 480,3PH

Notes:
- If required natural gas is provided by XCEL Energy during Tenant Design. Space air conditioning is from the Concourse VAV Air Handling Systems.

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Matrix C: DEN Concourse C East Expansion Concessions

DEN Concourse C East Expansion Concessions Matrix

Space		Plan Name						Mechanical											Plumbing							Electrical		
								Cooling Load				Cooking		Kitchen/ Dishwash Exhaust		Ventilation (CFM)			Domestic Cold Water		Domestic Hot Water	San. Sewer)	Grease Waste)	Vent	Gas			
Location	Category	Room Number	Plan Tag	Seating Internal for to Restaurant (Y/N)	Trash Chute Access (Y/N)	Dumb Waiter Shaft	Floor Area (S/F)	Allowance (SF/TON)	Total (Tons)	Chilled Water Flow Allowance (GPM)	Heating Hot Water Flow Allowance (GPM)	(Y/N)	Type (E, Gas, or E/G)	(Y/N)	Air Flow (CFM)	Dishwasher Exhaust	Hood Makeup from Outside	Makeup Air from Terminal	Service	Size (IN.)	Service	Size (IN.)	Size (IN.)	Size (IN.)	Size (IN.)	Allowance (AMPS)	Calculated Load (AMPS)	Voltage
Subcore 6E Concourse Level[1]	Concession Space	CCC_02_6E_ 025	Restaurant 1	Y	Y	Y	3200	300	10.7	20	15	Y	E/G	Y	4500/ 1400	2980	2700	1800	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	4	4	3	By Tenant (2400 CFH Allowance)	100	77	480/ 277V
Subcore 6E Concourse Level[1]	Concession Space	CCC_02_6E_ 026	Restaurant 2	Y	Y	Y	3200	300	10.7	20	15	Y	E/G	Y	4500/ 1400	2980	2700	1800	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	4	4	3	By Tenant (2400 CFH Allowance)	100	77	480/ 277V
Subcore 6E Concourse Level[2]	Retail	CCC_02_6E_ 023	Travel & Convenience	N	N	N	1000	300	3.3	5	1.25	N	N/A	N	N/A	235	N/A	N/A	Concourse CW Loop, Metered	0.75	Local Electric Water Heater in Space	4	N/A	3	N/A	100	6	480/ 277V
Subcore 6E Concourse Level[2]	Concession Space		Gourmet Coffee Kiosk	N	N	N	1000	300	3.3	5	1.25	N	N/A	N	N/A	930	N/A	N/A	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	4	3	3	N/A	100	24	480/ 277V
Subcore 6E Apron Level[1]	Kitchen	CCC_02_6E_ 023	Kitchen 1	N	N	Y	1400	300	4.7	15	10	Y	E/G	Y	4500/ 1400	N/A	2700	1800	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	4	4	3	By Tenant (2400 CFH Allowance)	100	67	480/ 277V
Subcore 6E Apron Level[1]	Kitchen	CCC_02_6E_ 023	Kitchen 2	N	N	Y	1400	300	4.7	15	10	Y	E/G	Y	4500/ 1400	N/A	2700	1800	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	4	4	3	By Tenant (2400 CFH Allowance)	100	67	480/ 277V
Subcore 6E Basement Level[3]	Concession Storage	CCC_00_6E_ 007	Storage	N	N	N	3858	1200	3.2	5	5	N	N/A	N	N/A	465	N/A	N/A	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	3	N/A	2	N/A	125	9	480/ 277V

DEN Concourse C East Expansion Concessions Matrix (Continued)

Space		Plan Name						Mechanical											Plumbing							Electrical		
Subcore 9E Concourse Level[1]	Concession Space	CCC_02_9E_ 025	Restaurant 1	Y	Y	Y	3200	300	10.7	20	15	Y	E/G	Y	4500/ 1400	2980	2700	1800	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	4	4	3	By Tenant (2400 CFH Allowance)	100	77	480/ 277V
Subcore 9E Concourse Level[1]	Concession Space	CCC_02_9E_ 027	Restaurant 2	Y	Y	Y	3200	300	10.7	20	15	Y	E/G	Y	4500/ 1400	2980	2700	1800	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	4	4	3	By Tenant (2400 CFH Allowance)	100	77	480/ 277V
Subcore 9E Concourse Level[2]	Retail	CCC_02_9E_ 023	Travel & Convenience	N	N	N	1000	300	3.3	5	1.25	N	N/A	N	N/A	235	N/A	N/A	Concourse CW Loop, Metered	0.75	Local Electric Water Heater in Space	4	N/A	3	N/A	100	6	480/ 277V
Subcore 9E Concourse Level[2]	Concession Space		Gourmet Coffee Kiosk	N	N	N	1000	300	3.3	5	1.25	N	N/A	N	N/A	930	N/A	N/A	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	4	3	3	N/A	100	24	480/ 277V
Subcore 9E Apron Level[1]	Kitchen	CCC_01_9E_ 015	Kitchen 1	N	N	Y	1400	300	4.7	15	10	Y	E/G	Y	4500/ 1400	N/A	2700	1800	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	4	4	3	By Tenant (2400 CFH Allowance)	100	67	480/ 277V
Subcore 9E Apron Level[1]	Kitchen	CCC_01_9E_ 015	Kitchen 2	N	N	Y	1400	300	4.7	15	10	Y	E/G	Y	4500/ 1400	N/A	2700	1800	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	4	4	3	By Tenant (2400 CFH Allowance)	100	67	480/ 277V
Subcore 9E Basement Level[3]	Concession Storage	CCC_00_9E_ 005	Storage	N	N	N	3589	1200	3	5	5	N	N/A	N	N/A	430	N/A	N/A	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	3	N/A	2	N/A	100	9	480/ 277V

Notes:

[1]*If required natural gas is provided by XCEL Energy during Tenant Design. Cooling and heating are provided by the Concourse air conditioning systems.*

[2]*Cooling and heating are provided by the Concourse air conditioning systems.*

[3]*Apron secure storage.*